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AGRONOMIC AND GREENHOUSE GAS COMPARISON OF DIFFERENT NITROGEN FERTILIZER MANAGEMENT PRACTICES

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Final Report

The Effect of Nitrogen Fertilizer Placement, Formulation, Timing, and Rate on Greenhouse Gas Emissions and Agronomic Performance

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Table of Contents

Page

1. Introduction 1
2. Project Objective 3
3. Materials and Methods 4
   3.1 Nitrous Oxide Sampling 5
   3.2 Energy Analysis 6
4. Results and Discussions 8
   4.1 Agronomy Results 8
   4.2 Overall Summary: Yields and Yield Components 24
   4.3 Grain and Straw-N Concentrations and N Update 26
   4.4 Nitrous Oxide Emissions 30
5. Energy Analysis 36
   5.1 Effect of Drought on Measured Energy Performance Factors 37
   5.2 Treatment Effects on Gross and Net Energy Output 37
   5.3 Output/Input and Grain/Unit of Input Energy Ratios: Overview 45
   5.4 Conclusions 47
6. Overall Conclusions 48
   6.1 Acknowledgements 50
   6.2 References 50

Appendix I 58

1. Introduction

Increasing the efficiency of nitrogen (N) fertilizer uptake by crops improves the agronomic, economic, and environmental value of fertilizer N. The availability of fertilizer N to plants can be affected by its position in relation to plant roots. Band placement of urea below the soil surface increased recovery of N in plants in both conventional- and zero- tillage systems (Malhi and Nyborg 1991). The latter systems require all fertilizer nutrients be applied during the seeding operation. Seed-placed application of large volumes of fertilizer is not an option due to seedling damage, thus manufacturers have developed opener systems to separate the seed and fertilizer without compromising fertilizer uptake. These systems include side-band and mid-row band delivery. Although researchers have investigated the performance of side-band openers, there have been no agronomic comparisons between side-band and mid-row banded N. Farmers are unsure as to which fertilizer system performs best or if they perform the same.

There are serious concerns about nitrous oxide (N_2O) emissions associated with N fertilizer applications. Nitrous oxide is a powerful greenhouse gas and also depletes stratospheric ozone. Current estimates suggest that agricultural activities contribute approximately 60% of all Canadian anthropogenic N_2O emissions, with more than 50% of the agricultural total being associated with nitrogen (N) fertilizer use. The relationship between the amount of N applied and N_2O emitted is not necessarily linear, but is governed by a complex interaction between environmental conditions, soil properties, as well as the form, placement, and timing of the fertilizer N application. If N is applied when and where plants need it most, N-use efficiency should increase, leaving less free N in the soil for shorter periods of time, and N_2O emissions should be reduced. As indicated above, placing N fertilizer into bands increases crop uptake efficiency, but concentrating fertilizer into bands can also cause localized alterations in soil pH, osmotic potential, and free NH_3 concentrations which may also influence direct N_2O losses. Changing the spread of banded fertilizer due to alterations in opener configuration and doubling of the fertilizer rate per band with mid-row banded placement, both of which alter the localized concentration of applied N, may therefore have a considerable effect on the amount of N_2O emitted after fertilizer N application. In addition, studies in the United States (Breitenbeck and Bremner 1986a & b; Bremner et al. 1981) have suggested that losses of N_2O from anhydrous ammonia (AA) may be much higher (1.63% of N applied lost as N_2O) compared to other N sources (0.03 to 0.26%). This is of particular concern for western Canada where AA is used extensively. However, this research was carried out in locations with soil and climatic conditions, and N application rates and placement methods markedly different from western Canada. The actual contribution of N_2O from fertilizer use in the prairie region is highly uncertain, and the influence of fertilizer formulation is largely unknown.

In order to accurately assess the contribution of prairie agriculture to N_2O emissions, and identify opportunities for reducing those emissions, a better understanding of the influence that N source, placement, rates of application, and their interaction with soil and climatic variations is needed. Maximizing economic benefits and minimizing the potential for environmental damage are both clearly linked to the efficient management of nitrogen fertilizer.

2. Project Objective

This research provides much needed N_2O loss coefficients from representative crops and nitrogen management technologies in western Canada. The agronomic performance of the two most common fertilizer/seeding application systems were compared and energy use efficiencies calculated, providing important information to help producers make cost effective management decisions. The general objectives were: 1) to determine the influence of nitrogen fertilizer formulation, placement, and timing on N_2O emissions from representative western Canadian soils; 2) to compare the agronomic performance and nitrogen use efficiency of side-banded versus mid-row banded urea and anhydrous ammonia (AA) applied at seeding, as well as fall band of both formulations; 3) to calculate a total energy budget for the different formulations, placements, and timings of N fertilizer application.

Applied Questions:

- How much N from fertilizers is lost directly as N_2O under western Canadian conditions?
- Does fertilizer N source influence direct losses of N_2O?
- Does application time (spring vs. fall) influence direct losses of N_2O?
- Are direct losses of N_2O influenced by crop type?
  Does fertilizer placement influence agronomic performance and/or direct losses of N_2O?

3. Materials and Methods

Field experiments were established in four Saskatchewan soil-climatic zones, using canola, flax, and wheat as test crops. Experimental sites included Swift Current (Brown soil zone), Scott (Dark Brown), Indian Head (Black), and Star City (Dark Gray). Selected soil characteristics for each site are provided in **Table 1**. At each site, and separately for each crop, 17 treatments were arranged in a randomized complete block design (RCBD) in four replications. Plots dimensions were 3.1 m x 9.2 m with a 0.3 m boundary between each plot. A complete list of treatments is provided in **Table 2**. Treatments included the following factors: 1) N placement (Side-banded, mid-row banded and broadcast); 2) N fertilizer formulation (Urea and AA); 3) N application timing (fall and spring); 4) N rate; and 5) phosphorus (P) placement (Side-banded P and P placed with the seed).

Seed row openers were located at 25 cm (10 in) spacing using Flexi-Coil Stealth openers for the side-banded treatments and Bourgault knives with Bourgault mid-row coulter banders (placed between every second set of knives) for the mid-row banded treatments. On-row packing with V shaped packers was done in all the treatments.

A blanket application of K_2SO_4 was broadcast prior to seeding at all sites to ensure sufficiency of these nutrients. All sites received P fertilizer (11-51-0), at rates of 17 kg P_2O_5 ha^{-1} at Scott and Swift Current and 23 kg P_2O_5 ha^{-1} at Melfort and Indian Head. Nitrogen fertilizer rates were, check (no N fertilizer applied, but the P fertilizer contained 4 kg N ha^{-1} at Scott and Swift Current and 5 kg N ha^{-1} at Melfort and Indian Head), recommended rate (1.0x), one-half the recommended rate (0.5x), and one and one-half the recommended rate (1.5x). The recommended rate was 80 kg N ha^{-1} at Melfort and Indian Head and 60 kg N ha^{-1} at Swift Current and Scott. Phosphorus was placed with the seed in all cases except for the side-banded urea treatments where both N and P were placed in the side-band. An additional side-banded urea treatment (1.0x) with seed placed P was included for comparative purposes.

Canola (InVigor 2273 in 2000; InVigor 2663 in 2001 and 2002) was seeded at 5-6 kg ha^{1}, while flax (Norlin in 2000 and Bethune in 2001 and 2002) was seeded at 63 kg ha^{-1} at all locations. Spring wheat (AC Barrie in 2000 and 2001 and AC Eatonia in 2002) was seeded at 134 kg ha^{-1} for Indian Head and Star City, and 90 kg ha^{-1} for Scott and Swift Current. Crops were rotated in the following sequence: flax was grown on spring wheat stubble, canola on flax stubble, and spring wheat on canola stubble. Crops were direct seeded into standing stubble using a 10 ft, 4 tank PAMI pneumatic plot seeder configured to apply either AA or urea in addition to seed and P requirements.

Plant emergence and head counts were taken on one-meter row lengths from two positions in each plot. Plant counts were conducted on all plots about 2 weeks after emergence; head counts were taken after soft dough stage on the wheat plots only.

Total biomass was determined on all plots by collecting two ½ -m row lengths by hand from two positions in each plot. The samples were bulked, dried (temperatures ≤ 60 °C), and weighed. Grain yields were determined using a plot combine. Grab samples of straw were collected from behind the combine. A representative grain and straw sample was ground and analysed for carbon and nitrogen contents. Bushel weights and 1,000 kernel seed weights were also determined using standardized procedures.

All dependent variables were analyzed with the PROC MIXED procedure of SAS (SAS Institute Inc. 1996) with the REML option with treatments fixed and replications random. Single df contrast comparisons were done between several groups: 1) Side-banded N placements (Treatments 1, 2, 3, 9, 10, 11) vs. mid-row banded N placements (Treatments 4, 5, 6, 12, 13, 14); 2) Broadcast urea (Treatment 8) vs. Banded urea (Treatments 2, 5); 3) Urea (Treatments 1-6) vs. AA (Treatments 9-14); 4) Fall banded N applications (Treatments 7, 15) vs. spring banded N applications (Treatments 2, 5, 10, 13); and 5) Side-banded phosphorus (Treatment 2) vs. phosphorus placed with the seed (Treatment 17). Linear, quadratic and cubic effects of N rate were determined by orthogonal contrasts. All contrasts were done for individual groups, combined and their interactions. 'Significance' in the text refers to $P < 0.05$, if the P value is not given.

3.1 Nitrous Oxide Sampling

Gas samples were collected using vented soil chambers similar to those described by Lessard et al. (1994). Plexi-glass frames (22 cm x 45.5 cm x 15 cm high) were inserted into the soil to a depth of 5 cm. The frames were designed to fit snugly between crop rows. Care was taken to ensure that the frames encompassed the fertilizer bands.

N_2O flux was estimated from the concentration change in the chamber headspace over a 30 or 60 minute collection period. Samples were drawn from the headspace using disposable 20 ml polypropylene syringes. The gas samples were then injected into pre-evacuated 13 ml exetainers for transport to the laboratory. The concentration of N_2O in the samples was determined using a gas chromatograph equipped with an electron capture detector. The field plots were sampled for N_2O emissions about twice weekly from snow melt until the end of July when soil-water contents were high and the potential for N_2O loss was greatest. Sampling frequency was reduced to once a week or less during the latter part of the season when soil-water contents were low.

N_2O emissions stimulated by fertilizer N placed in bands are most intense near the band, and decrease with increasing distance from the band. Fertilizer is placed between every crop row on side-row band treatments, thus samples collected from chambers enclosing the entire inter-row area will include a representative proportion of soil that is and isn't influenced by the fertilizer band. Conversely, fertilizer is placed between every second crop row on the mid-row band treatments, thus the soil volume between the alternate crop rows (the inter-row area not receiving fertilizer) will be largely unaffected by the fertilizer band. Thus, a representative flux measurement should be an average of the two inter-row areas. We assumed that emissions from the inter-row area not receiving fertilizer would be unaffected by the fertilizer band and should be similar to the check treatments. Accordingly, emission estimates from the mid-row band treatments were calculated by averaging the flux from the inter-row area receiving fertilizer N with the flux from the check treatments (used as a proxy for the inter-row area not receiving fertilizer).

Seasonal estimates of N_2O emissions were calculated by interpolating between data points and integrating over time assuming a constant flux (Lemke et al., 1998). Seasonal estimates were analysed using GLM procedure in SAS, and $LSD_{0.01}$ or contrasts were used for mean separation. Linear and quadratic effects of N rate were determined by orthogonal contrasts. All contrasts were done for individual groups, combined and their interactions. 'Significance' in the text refers to $P < 0.1$ if the P value is not given.

3.2 Energy Analysis

The energy performance of the nitrogen fertilizer management systems was determined using methods described by Zentner et al. (1998). This involved identifying all direct and indirect non-renewable energy going into the manufacture, formulation, packaging, distribution, transportation, maintenance, and application of all inputs used in each crop production system. A 907 ha representative farm, with a typical complement of equipment for each treatment, was used to extrapolate the research plot data to a farm-level basis.

The physical quantities of inputs used were converted to energy values using appropriate and the most recent energy coefficients taken from the literature and as summarized by Nagy (1999) and Zentner et al. (1998) (**Table 3**). Recommended depths of tillage (where appropriate) and travel speeds were assumed for all field operations. Quantities of fuel and lubricants used by tractors and other powered machinery were as reported by Saskatchewan Agriculture and Food (1999). Grain used as seed was not included as an energy input; instead, it was subtracted from the harvested grain yield for each crop. Energy associated with human labor was not included in the analysis because it has been shown in earlier studies to account for less than 0.2% of total energy input for most cropping systems (Zentner et al., 1984). No allowance was made for energy removed from the soil in the form of plant nutrients, energy captured in terms of soil organic matter increases or losses (Coxworth et al., 1994, 1995), nor for that which was captured directly from the sun by the growing plants. The analysis also excludes heating and electrical energy used for the home and farm buildings, and energy associated with transportation and subsequent processing of the grains beyond the point of initial sale (i.e., delivery to a local elevator or processing facility). Presumably, these latter energy expenditures would occur regardless of how the grains were produced.

Output from the cropping systems was taken as gross energy content of the harvested grain less the seed requirements, based on bomb calorimeter analyses (direct combustion) of representative samples of each grain type (Nagy, 1999). Energy in the crop residue was not included as energy output of the treatments since it was returned to the land.

Energy efficiencies or intensities of the cropping systems were calculated as (i) net energy produced (energy output minus energy input); (ii) ratio of energy output to energy input; and (iii) quantity of grain produced per unit of energy input.

The energy performance results were expressed on a per hectare basis. All data were subjected to analysis of variance using the statistical methods described previously in the agronomy section.

4. Results and Discussions

Swift Current experienced an unusually warm May during 2000; otherwise mean monthly air temperatures were similar to the long-term means for all sites in all three years of this study (**Table 4**). Scott and Indian Head received about average precipitation during the 2000 growing season, but precipitation was above average at Star City and Swift Current. Late fall and winter were dry at all sites with snowfall being particularly low at Scott and Swift Current. The 2001 growing season was dry at all locations. Indian Head received only 30% of long-term mean precipitation, while Swift Current, Scott, and Star City received 60%, 63%, and 73% respectively. All sites received very limited snowfall during the over-winter period, and conditions remained very dry during the early part of the 2002 growing season. Conditions remained dry throughout the balance of the season at Scott resulting in complete crop failure. Above average precipitation at Swift Current and Indian Head during the latter part of the growing season resulted in modest crop yields at these two locations. At Star City, the rains came too late (July) for the wheat crop to recover. The flax crop recovered enough to provide poor but harvestable yields, and the canola produced modest yields.

4.1 Agronomy Results

4.1.1 Swift Current

In 2000, temperature and overall precipitation were generally above normal during the growing season (May-August), although rainfall in August was quite low (**Table 4**). In 2001, the temperature was above average during most of the growing season, with very low precipitation. The moisture condition in the early spring of 2002 was poor due to depletion of soil moisture in 2001 and low precipitation in May, but precipitation was well above normal during the rest of the growing season; temperature was near normal throughout.

Wheat: The environment had a major impact on the grain yield and biomass production (**Table 5**). The overall mean yield in 2000 (3.7 t ha^{-1}) was about five times the yield in 2001 (0.7 t ha^{-1}) and three times the yield in 2002 (1.5 t ha^{-1}). In addition to drought, sawfly damage was also severe in 2001. A solid stem wheat variety (AC Eatonia) was seeded in 2002 to minimize sawfly damage.

Effect of N placement: Statistical analysis indicated no significant placement × formulation or placement × rate interactions for any agronomic variables in any year. Therefore only the overall contrasts between side-banded and mid-row banded treatments are presented in **Figure 1**. No significant differences in agronomic performance were found between side-banded and mid-row banded treatments in 2000, although a considerable crop stress on the medium and high side-banded urea treatments was visually observed in the early growing season. These symptoms were no longer apparent by the flag leaf stage.

In 2001, mid-row banded treatments achieved slightly higher straw yield (0.1 t ha^{-1}) than side-banded treatments, which was associated with a higher plant density ($P < 0.05$). There were no significant differences between side-banded and mid-row banded treatments in heads per plant or kernel weight. In 2002, side-banded treatments harvested higher grain yield and straw yield ($P < 0.05$) than mid-row treatments, but treatment difference was only 0.2 t ha^{-1} for grain yield and 0.3 t ha^{-1} for straw yield.

Banded N applications consistently had higher yields than the broadcast N treatment (urea at medium rate) although the difference was only significant in 2002 (**Figure 2**). In 2000, the mid-row banded treatment had lower plant density ($P < 0.01$), which was compensated by more heads per plant.

Effect of N formulation: There were no significant formulation × placement or formulation × rate interactions on any agronomic variables. No significant differences in grain yield or straw yield between urea and AA treatments were found in any year (**Figure 3**). In 2000, AA treatments had higher plant density ($P < 0.01$), but less heads per plant ($P < 0.05$) than urea treatments. The AA treatments also had significantly more heads per plant than urea treatments in 2001, but the actual difference was very small (0.2 heads plant ^{1}).

Effect of timing: Contrasts showed that, in most cases, fall N applications did not differ from spring-banded N treatments at the medium rate in terms of agronomic performance, except that spring applications had slightly higher yield ($P = 0.06$) and significantly higher plant density ($P < 0.05$) than fall applications in 2002 (**Figure 4**).

Effect of N fertilizer rate: Statistical analyses indicated that there were no significant rate × placement or rate × formulation interactions on agronomic performance. **Figure 5** shows that grain yield was not significantly responsive to fertilizer in 2000, but straw yield responded linearly to N rate. Heads per plant tended to increase, but plant density and kernel weight tended to decrease with increasing N, although differences were not significant. In 2001, neither grain yield nor straw yield responded to N. There was a trend for plant density to decrease with increasing N (not significant). Although kernel weight was linearly reduced with increasing N, the actual change of kernel weight was quite small. In 2002, grain yield and straw yield increased linearly with increasing fertilizer up to the recommended rate. Plant density tended to decrease for the treatment with more than the recommended N rate.

Effect of P placement: In general, different phosphorus placements did not result in differences in agronomic performance except that side-banded P treatment had lower kernel weight ($P < 0.001$) than the seed-place P treatments in 2002 (**Figure 6**).

Summary: In general, differences in agronomic variables between any groups were small. Straw yield and heads per plant tended to be more sensitive to N rate than other variables, although grain yield tended to be lower in both 2000 and 2001 when N was fall rather than spring applied, the difference was significant in 2002.

Canola: Similar to wheat, the environment had a major impact on the grain yield in canola at Swift Current (**Table 4**). The average yield in 2000 (1.7 t ha^{-1}) was about 2.4 times that of 2001 (0.7 t ha^{-1}) and 1.5 times that of 2002 (1.1 t ha^{-1}). Considerable lodging was observed in 2000.

Effect of N placement: Statistical analysis indicated no significant placement × formulation or placement × rate interaction for any agronomic variable in any year. Therefore, only overall contrasts between side-banded and mid-row banded treatments are presented (**Figure 7**). There was no significant difference between the two band placements for any variable, except that mid-row banded had significantly higher kernel weight than side-banded in 2000 ($P < 0.001$) and 2001($P < 0.05$). Broadcast application had significantly lower seed yield compared to band placements (urea at medium rate) in 2002, and higher kernel weight than the side-row placement (but not the mid-row) in 2000 (**Figure 8**).

Effect of N formulation: There were no interactions of formulation × placement or formulation × rate for contrasts between urea and AA spring-banded treatments. The AA treatments had higher yield than urea treatments in 2001 ($P < 0.05$), although the actual difference was small (**Figure 9**). No other treatment differences were observed.

Effect of timing: Fall applications did not differ significantly from spring-banded treatments at the same fertilizer rate (medium) for any agronomic variables (**Figure 10**). Fall applications only slightly ($P = 0.06$) increased straw production in 2001 and slightly reduced plant density in 2002 ($P = 0.06$).

Effect of N rate: In general, seed yields and straw yield responded linearly to fertilizer rate in each year, although grain yield in the high N treatment was slightly less than on the medium rate in 2002 (**Figure 11**). The degree of increase in straw yield was reduced when the N rate was higher than the low rate level in 2000 and the degree of increase was quite small in 2001. Although plant density did not respond to fertilizer rate significantly, high rates of fertilizer tended to reduce plant density in 2001 and 2002. In 2001, plant density was linearly reduced by side-banded urea ($P = 0.05$) and AA ($P = 0.08$). Kernel weight increased linearly with fertilizer rate in 2002.

Effect of P placement: The side-banded P treatment had lower ($P < 0.05$) yield in 2001 and slightly higher ($P = 0.07$) straw production in 2002 (**Figure 12**) compared to seed-placed P. There were no other significant differences in agronomic performance between the two placements of phosphorus.

Summary: Seed and straw yields showed a significant linear response to N rate in all three years, however differences in agronomic performance between N-managements were small and infrequent. Grain yield was significantly higher in 2001 when P was seed-placed compared to side-banded.

Flax: Similar to other crops at Swift Current, flax yield in 2000 was the highest (1.8 t ha^{-1}), followed by 2002 (1.2 t ha^{-1}) and 2001 (0.7 t ha^{-1}) (**Table 7**).

Effect of N placement: In general, differences in agronomic performance between side-banded and mid-row banded treatments were not significant for flax at Swift Current, except that mid-row banded treatments had higher kernel weight than side-banded treatments (**Figure 13**) in 2002. The formulation × placement interaction was significant for plant density in 2002 ($P < 0.05$). The mid-row banded treatment had higher plant density compared to the side-banded treatment for AA ($P < 0.05$) but not urea.

Banded treatments had higher grain yield than the broadcast treatment (urea at medium rate) in 2001 ($P < 0.01$), but not in other two years (**Figure 14**). The broadcast treatment had higher plant density in 2000 ($P < 0.01$) and lower kernel weight in 2002 ($P < 0.05$), compared to the mid-row band treatment.

Effect of N formulation: Fertilizer formulation had no significant effect on grain yield, but straw yields were significantly higher when N was applied as AA rather than urea in 2000 and 2001 (**Figure 15**). Plant density tended to be higher for AA treatments compared to urea treatments, but the difference was only significant in 2000.

Effect of timing: In most cases, there were few differences in agronomic performance between fall-banded and spring-banded treatments, although grain yield tended to be higher when N was spring rather than fall applied, however the difference was only significant in 2001 ($P < 0.05$). In 2000, plant density was lower ($P < 0.01$) on plots receiving N in the spring compared to fall (**Figure 16**).

Effect of N rate: Grain yield did not respond to fertilizer rate in 2000 (**Figure 17**). There was a significant quadratic response in 2001, but the actual difference was very small. In 2002, yield increased linearly over the first two increments of N applied. Straw production responded to the fertilizer rate in a similar fashion to that of gain yield. Plant density did not respond significantly to fertilizer rate, however high rates tended to reduce density each year. The kernel weight was negatively related to fertilizer rate in 2001, but not in the other two years.

Effect of P placement: Side-banded P had higher ($P < 0.05$) yield in 2002 and slightly higher ($P = 0.08$) plant density in 2000 compared to seed-placed P (**Figure 18**). There were no other differences in agronomic performance between P placements.

Summary: In most cases, treatment effects on agronomic variables were relatively small in flax. The yield was only linearly responsive to the first two increments of N rate in 2002. Higher N applications tended to reduce plant density. A 3-year trend for grain yield to be lower on treatments receiving N in the fall compared to spring was noted, but the difference was only significant in 2001. Grain yield tended to be lower on broadcast compared to banded treatments in 2001.

4.2.1 Indian Head

Temperatures were unusually cool and precipitation was above average during May and June at Indian Head in 2000 (**Table 4**). Conditions were very dry in the whole 2001 season and the early part of 2002. Precipitation was near to slightly above normal from June to August of 2002.

Wheat: Despite considerable differences in yearly rainfall, average wheat yields did not differ significantly from year to year. Average yields in 2000 were 2.2 t ha^{-1}, 2.0 t ha^{-1} in 2001, and 2.2 t ha^{-1} in 2002 (**Table 8**).

Effect of N placement: The difference in grain yield between side-banded and mid-row banded treatments was not significant in 2000 (**Figure 19**). Side-banded treatments had significantly higher straw yield, higher plant density and lower heads per plant than mid-row banded treatments for urea fertilizer, but treatment differences were not significant for AA (**Table 8**). In 2001, side-banded treatments significantly reduced plant density suggesting poorer seedbed quality or possibly seedling damage. However, an increase ($P < 0.001$) in heads per plant by side-band treatments compensated the loss of plants and resulted in similar grain yields between the two placement treatments. Although grain yield on the side-banded treatment was significantly ($P < 0.01$) higher than on the mid-row banded treatment in 2002, the actual difference was quite small (0.1 t ha^{-1}).

The mid-row banded treatment had lower plant density ($P < 0.05$), but higher heads per plant ($P < 0.05$) than the broadcast treatment in 2000 (**Figure 20**). In 2001, both banded treatments had higher grain yield than the broadcast treatment. The side-banded treatment had lower plant density ($P < 0.05$), but higher heads per plant ($P < 0.01$). In 2002, both banded treatments had significantly lower plant density compared to the broadcast treatment.

Effect of N formulation: Urea fertilizer treatments produced significantly higher yield than the AA fertilizer treatments in 2000 and 2001, although the actual difference was small (0.1 t ha^{-1}, **Figure 21**). AA treatments had higher plant density compared to the urea treatments in 2002.

Effect of timing: In general, there were no significant differences in agronomic performance between fall banded and spring banded treatments, except that fall banded tended to achieve higher plant density each year (**Figure 22**).

Effect of N rate: There was a linear effect of N fertilizer rate on grain yield each year, although the increase was small when the rate was higher than the low level (**Figure 23**). The response of straw production to N rate was similar to that of yield. Other agronomic characteristics did not response to N rate significantly, except that linear responses to N rate from very low to medium were found for heads per plant and kernel weight in 2000.

Effect of P placement: No significant differences in agronomic performance were found between seed placed and side-band placed P, except that the side-band treatment had higher ($P < 0.01$) kernel weight in 2000 (**Figure 24**).

Summary: In most cases, differences in agronomic variables between any groups were relatively small in wheat at Indian Head and treatment differences were not consistent. Broadcast and fall banded treatments tended to have higher plant density than spring-banded treatments. Treatments receiving N as urea rather than as AA had higher grain yield in both 2000 and 2001.

Canola: The yearly difference of grain yield for canola was larger than that for wheat at Indian Head (**Table 9**). The average yield was 2.5 t ha^{-1} in 2000, which was about 1.7 and 1.9 times of that in 2001 (1.5 t ha^{-1}) and 2002 (1.3 t ha^{-1}), respectively.

Effect of N placement: A significant effect of fertilizer placement on canola yield was found in 2001 (**Figure 25**). Side-band treatments had markedly lower yield compared to mid-row band treatments ($P < 0.001$), which was attributed to poor emergence as a result of shallow seeding with the side-banded opener. On June 12, the plant density of side-band treatments only had about 1/3 that of mid-row band treatments. The plant density observed on July 3, following rainfall, did not differ significantly among treatments (data not shown), suggesting that delayed emergence was the cause of yield reduction in side-band treatments. Fertilizer form × placement interactions were significant for yield and for plant density. Side-band treatments had significantly lower yield and lower density than mid-row treatments for both fertilizer forms, but the reduction of yield and plant density for AA was higher than that for urea (**Table 9**). In 2002, side-band treatments had lower ($P = 0.07$) plant density than mid-row band treatments for AA. For urea, however, side-band treatments had significantly ($P < 0.05$) higher plant density (**Table 9**).

Lower yield and lower plant density on side-band treatments compared to the broadcast treatment were observed in 2001 (**Figure 26**). In 2002, the side-band treatment had slightly lower yield compared to the broadcast treatment (**Figure 26**), but it was not related to plant density as the side-band treatment actually had higher plant density ($P < 0.05$).

Effect of N formulation: Urea treatments tended to have higher yields compared to AA in 2000 and 2001, but the difference was only significant ($P < 0.001$) in the latter year (**Figure 27**). The significance of the yield increase by urea over AA was much greater for side-band treatments ($P < 0.001$) than for mid-row treatment ($P = 0.07$). AA applications had significantly ($P < 0.01$) lower plant density (10 m^{-2}) compared to urea applications (26 m^{-2}) in the side-band treatments, but there was no difference in plant density in the mid-row band treatments. In 2002, treatments receiving AA had significantly higher plant density than urea treatments for mid-row placement ($P < 0.01$), but not for side-band placement (**Table 9**).

Effect of timing: No significant fertilizer form × timing interactions were found for agronomic performance (**Figure 28**). Fall band treatments out-yielded spring band treatments ($P < 0.05$) in 2000 and 2001. The yield gain of fall band treatments in 2001 was attributed to better plant establishment ($P < 0.001$).

Effect of N rate: **Figure 29** showed that canola yield tended to respond linearly to N rate in each year. Although the overall yield response was not significant in 2001, yields significantly responded to N rate linearly and quadratically for each fertilizer form/placement, except the treatment of urea side-banded (**Table 9**). Straw production did not respond to N rate significantly in 2000 or 2001. In 2002, straw yield increased linearly until the N application reached the recommended rate.

Effect of P placement: Side-band placed P had lower yield ($P < 0.001$), but higher plant density ($P < 0.05$) compared to seed-placed P in 2002 (**Figure 30**). There were no other significant differences in agronomic performance between the two phosphorus placements.

Summary: In most cases, differences in grain yield and other variables between any groups were relatively small in canola at Indian Head. Grain yield tended to be higher on seed-placed compared to side-band placed P in all three years, but the difference was only significant in 2002. Yields were also significantly higher when N was applied in the fall rather than in the spring in 2000 and 2001. Side-banded treatments had markedly lower yield compared to mid-row banded treatments in 2001, which was associated with lower plant density.

Flax: In contrast to canola, the highest grain yield was achieved in 2002 for flax at Indian Head (2.0 t ha^{-1}), followed by 2000 (1.6 t ha^{-1}) and 2001 (1.2 t ha^{-1}) (**Table 10**).

Effect of N placement: In 2000, mid-row banded treatments had significantly ($P < 0.001$) higher plant densities than side-banded treatments, but this did not result in significant differences in grain yield or straw yield (**Figure 31**). In 2001, the fertilizer form × placement interaction for yield was significant. Side-banded treatments had higher yield compared to mid-row banded treatments for AA ($P < 0.01$), but not for urea (**Table 10**). Side-banded treatments had higher straw yield compared to mid-row banded treatments for both fertilizer formulations. The fertilizer form × placement interaction for density was also significant in 2001. Side-banded treatments had significantly lower plant densities than mid-row band treatments for both fertilizer formulations, but the reduction for urea was much higher than for AA (**Table 10**). It appears that the differences in yield and straw production between two fertilizer placements were not related to plant density. In 2002, mid-row banded treatments had slightly ($P = 0.09$) higher yield than side-banded treatments. The fertilizer form × placement interaction for density was again significant. Side-banded treatments had significantly lower plant density than mid-row band treatments for AA, but not for urea (**Table 10**).

Contrasts between treatments of side-banded and broadcast urea at medium rate showed that side-banding reduced plant density slightly in 2000 and significantly in 2001 (**Figure 32**).

Effect of N formulation: Yield differences between two fertilizer treatments were small (**Figure 33**). In 2000, urea fertilizer produced slightly ($P = 0.08$) more yield than AA fertilizer. In 2001, urea treatments had significantly higher yield compared to AA treatments for mid-row band, but the actual difference was only 0.1 t ha^{-1}. AA had higher plant densities than urea on side-banded treatments ($P < 0.05$), but not on mid-row treatments.

The yield difference was not significant in 2002, but straw yields tended to be higher on AA than on urea treatments. The AA treatments had higher plant densities compared to urea treatments, but it was only significant for the mid-row band placement ($P < 0.01$).

Effect of timing: There were no significant differences in agronomic performance between fertilizers applied in the fall and in the spring, except that spring applied fertilizer had lower plant density than fall applied fertilizer in 2001 (**Figure 34**). The soil was wet in the spring which may have resulted in greater soil compaction and more difficulty in getting good seed to soil contact. Dry windy conditions following the seeding operation would have aggravated this problem.

Effect of N rate: In 2000 and 2002, grain yields markedly increased with the first increment of N (**Figure 35**). In 2001, no significant yield response to N rate was found for any fertilizer formulation or placement, except that yield increased linearly on side-banded AA ($P < 0.01$) with increasing N (**Table 10**). Plant densities tended to be reduced with increasing N rate in 2001 and 2002. This trend existed for all treatments, especially the side-banded treatments (**Table 10**).

Effect of P placement: There were no significant differences in agronomic performance between the two phosphorus placements, except that side-band placed P had lower straw yield ($P < 0.05$) and higher plant density ($P < 0.05$) compared to the seed-placed P treatments in 2000 (**Figure 36**).

Summary: Treatment differences for agronomic variables were not consistent for flax at Indian Head, although the side-banded treatments tended to reduce plant density. In most cases, grain yield only responded to the first increment of N.

4.3.1 Star City

Wheat: The environment had a major impact on the grain yield in wheat (**Table 11**). The overall average yield was the highest in 2000 (2.3 t ha^{-1}). Severe droughts resulted in yields for 2001 and 2002 that were only about 43% (1.0 t ha^{-1}) and 13% (0.3 t ha^{-1}) of that in 2000, respectively. An analysis and discussion of the 2002 results is provided for completeness, however, the virtual failure of the wheat crop in this year makes the validity of the observations rather questionable.

Effect of N placement: There were no significant differences in wheat yield between two N placements in any year (**Figure 37**). Opposite treatment differences in straw yield were found between 2000 and 2001. Mid-row treatments had higher straw yield in 2000, but lower straw yield in 2001 for both fertilizer forms, but the differences were only significant for urea (**Table 11**). Mid-row band had less heads per plant in 2000 and lower kernel weight in 2002 than side-band (note that kernel weight data was not collected in 2000). Mid-row band treatments tended to have higher plant densities than side-banded treatments for both fertilizers, although the difference was not significant in 2001. Differences in plant density did not translate into significant differences in yield.

The side-banded urea treatment had higher yield than the broadcast treatment in 2002 ($P < 0.05$), which was associated with more heads per plant and higher kernel weight-even though plant density was slightly lower (**Figure 38**). The mid-row band treatment had lower straw yield than the broadcast treatment in 2000.

Effect of N formulation: There was no interaction between formulation and placement in agronomic performance. In general, grain yield and straw yield differences were quite small, but AA produced significantly higher straw yield compared to urea in 2000 (**Figure 39**). AA treatments had much higher plant density than urea treatments in 2002, but grain yield and kernel weight was actually reduced.

Effect of timing: Fall applied N had significantly lower grain yield in 2001 compared to spring applied N (**Figure 40**). Fall banded AA treatments had significantly lower plant densities than spring side-banded AA in 2000 and 2002 (**Table 11**).

Effect of N rate: There was a marked increase in grain yield with N application in 2000, although the magnitude of the increase was reduced with each additional increment of N (**Figure 41**). The yield increase was associated with a similar increase in heads per plant. In 2001, the increased yields were very small after the first increment of N applied. The response pattern of straw yield to N rate was similar to that of grain yield in 2000 and 2001, but yield increased more markedly with increasing N up to the recommended rate. Plant density did not respond to N rate, except in 2002 when plant density was linearly reduced with the increasing rates of urea (**Table 11**). Kernel weight responded negatively to N rate in 2002, but the actual change of kernel weight was very small after the first increment of N applied.

Effect of P placement: There were no significant differences in agronomic performance between two phosphorus placements, except that side-band placed P had lower plant density ($P < 0.01$), but more heads per plant ($P < 0.001$) compared to seed-placed P in 2000 (**Figure 42**).

Summary: There were few significant treatment differences in grain yield or agronomic variables for wheat at Star City. Treatments with fall applied N had lower grain yield than spring applied N in 2001. Side-banded treatments tended to have lower plant density than mid-row banded treatments, but this did not result in significant differences in grain yield.

Canola: The overall average canola yield was the highest in 2000 at Star City (2.5 t ha^{-1}), followed by 2002 (1.5 t ha^{-1}) and 2001 (0.7 t ha^{-1}) (**Table 12**).

Effect of N placement: No significant difference in grain yield between two N placements was found in any year (**Figure 43**). Side-banded treatments tended towards higher straw yield in each year but this was only significant in 2000. Side-banded treatments had lower plant density than mid-row banded treatments in 2000 and 2002.

Mid-row banded urea had lower grain yield than the broadcasted treatment in 2000, but banded treatments tended to produce higher straw yield (**Figure 44**). In 2002, both banded treatments produced higher grain yield, which might be attributed to their higher plant densities.

Effect of N formulation: Grain yield on treatments receiving AA was higher than on those receiving urea in 2000 (**Figure 45**). In 2001, AA produced slightly lower yield, which was associated with higher plant density, but lower kernel weight. The plant density was low for both fertilizer treatments in 2002, but was higher on urea treatments compared to AA treatments.

Effect of timing: The timing × form interaction was significant for grain yield in 2000 (**Figure 46**). Fall banded treatment had lower yield for AA (0.5 t ha^{-1}, $P < 0.01$), but higher yield for urea (0.3 t ha^{-1}, $P < 0.05$) compared to spring banded treatments. In 2002, spring banded treatments had higher grain and straw yields than fall banded treatments, which was associated with their higher plant density.

Effect of N rate: Grain yield responded linearly to N additions in each year, but the magnitude of the increase was less for treatments with N rates higher than the first increment in 2000 and higher than the recommended rate in 2001. The increase was very low in 2002 (**Figure 47**). Straw yield increased linearly with the increases of N in each year. Straw yields tended to respond to N rate linearly through all increments for AA, but not to the last increment for urea (**Table 12**). Although kernel weight responded to N rate linearly and quadratically in 2001, changes over all increments were very small.

Effect of P placement: The grain yield of side-banded P placement was significantly lower in 2000, but slightly higher in 2002 compared to seed-placed P (**Figure 48**). There were no other significant differences in agronomic performance between the two phosphorus placements.

Summary: Although canola responded linearly to N applications in all years, there were few significant treatment differences in grain yield or agronomic variables at Star City. Broadcast urea had lower yields than banded in 2002, but higher yield than mid-row banded urea in 2000. Spring banded N had significantly higher yields compared to fall banded N in 2002. Seed-placed P treatment had higher grain yields than side-placed P in 2000, as did AA treatments compared to urea treatments.

Flax: Similar to wheat, the overall average yield was the highest in 2000 (1.9 t ha^{-1}) (**Table 13**). Severe droughts resulted in yields for 2001 and 2002 that were only about 63% (1.2 t ha^{-1}) and 42% (0.8 t ha^{-1}) of the yield in 2000, respectively.

Effect of N placement: There were no significant differences in grain yield between the two N placements for flax at this site. Side-banded treatments had higher straw yield in 2000, and lower plant density in 2001 compared to mid-row banded treatments (**Figure 49**). In 2002, side-band treatments had significantly lower straw yield, but higher kernel weight. The broadcasted urea treatment did not differ from banded treatments, except that the mid-row banded treatment produced significantly less straw yield in 2000, but more straw yield in 2002 (**Figure 50**).

Effect of N formulation: AA treatments had significantly higher grain yield than urea treatments in 2001 (**Figure 51**).

Effect of timing: Spring banded treatments tended to produce higher grain yield and straw yield in two years (2001 and 2002) compared to fall-banded treatments (**Figure 52**). In 2001, the timing × fertilizer formulation interaction for plant density was significant ($P < 0.01$). The fall-banded treatment had significantly higher plant density than the spring-banded treatment for AA ($P < 0.01$), but not for urea (**Table 13**).

Effect of N rate: Grain yield did not generally respond to N rate. Straw yield increased linearly with the increasing N rate in 2000 and 2002, but the increase was small for the last increment (**Figure 53**). Plant densities tended to be reduced with increasing N in 2001.

Effect of P placement: Side-band placed P had higher yield and higher kernel weight ($P < 0.05$) compared to seed-placed P in 2001 (**Figure 54**). No other significant differences in agronomic performance were noted.

Summary: In most cases, treatment differences in agronomic variables were relatively small and not consistent. Side-banded treatments, especially that of high rate AA, tended to have lower plant density in 2001 than mid-row banded treatments. Grain yields on treatments receiving N in the fall rather than in the spring tended to be lower in both 2001 and 2002, but the difference was only significant in the latter year. Side-row placed P had significantly higher yields compared to seed placed P, and AA treatments had significantly higher yields compared to urea in 2001.

4.4.1 Scott

Precipitation was low during the early part of the growing season in 2000 (**Table 4**). Severe drought conditions were experienced in both 2001 and 2002. Although the 2002 results are presented and discussed, all three crops were essentially a failure in that year. Consequently the validity of any observations made for 2002 may be suspect.

Wheat: The environment had a major impact on the grain yield of wheat. The overall average yield was the highest in 2000 (2.2 t ha^{-1}) (**Table 14**). Severe droughts resulted in yields in 2001 and 2002 that were only about 71% (1.5 t ha^{-1}) and 9% (0.2 t ha^{-1}) respectively, of the 2000 yield. A relatively high incidence of take-all root infection was noted in 2000.

Effect of N placement: **Figure 55** shows that side-banded treatments had higher grain yields and significantly ($P < 0.01$) lower straw yields than mid-row banded treatments in 2000. No difference in plant density, heads per plant or kernel weight were noted. Under the dry conditions early in the growing season, placement of N farther from the seed row with mid-row band may have delayed uptake by the crop. This may be one possible explanation for the observed yield differences. In contrast, side-band tended to have both lower grain and straw yield in 2001 (only significant for AA, **Table 14**). Visual observations in the early growing season suggested that the side-band treatments appeared more vigorous, possibly because they accessed fertilizer N earlier. This, in turn, may have led to more rapid depletion of moisture reserves, restricting available moisture at grain filling. Although side-band achieved slightly higher yield in 2002, the actual yield difference between two treatments was very small (0.03 t ha^{-1}). The placement × form interaction was significant for plant density in 2002. Mid-row treatments had higher plant density than side-band treatments for both fertilizer formulations, but the difference was only significant ($P < 0.001$) for AA (**Table 14**).

Band placed urea had higher grain yield than the broadcast treatment in 2000 (**Figure 56**). The spring broadcast treatment displayed very evident N deficiency symptoms early in the growing season in 2000. Symptoms were less evident later. It is likely that the N was stranded in dry soil at the surface, and did not become available to the crop until precipitation moved it deeper into the soil. Band placed urea also tended to have higher grain yield than the broadcast treatment in 2002, although the differences were not significant.

Effect of N formulation: In 2000, AA treatments had significantly ($P < 0.01$) lower grain yield and slightly lower kernel weight than urea treatments (**Figure 57**). No explanation for this difference can be provided at this point, but notes taken during the growing season do suggest that a poorer response to AA was evident at the vegetative stages of growth. No significant differences were found in the other two years, except that urea treatments had significantly higher plant density than AA treatments for side-banded placement, but not for mid-row banded treatments in 2002 (**Table 14**).

Effect of timing: In 2000, fall banded N had significantly higher grain yield and slightly higher straw yield than spring banded N, which may have been associated with higher plant density (**Figure 58**). Fall band applications also resulted in higher density in 2002, although they had slightly lower density in 2001 compared to spring banded treatments.

Effect of N rate: Grain yield, straw yield, heads per plant and kernel weight linearly responded to increasing N rates in 2000 (**Figure 59**). Wheat suffered from relatively high levels of take-all root rot infection. Severity appeared greater on unfertilized checks, but this may have been misleading as the N fertilized treatments may have been better able to tiller and compensate for this disease infection, thus reducing the proportion of visibly affected heads without affecting the numbers of infected plants. In the other two years, all variables were either not significantly responsive to the change of N rate or the actual change was too small to be of consequence.

Effect of P placement: There were no significant differences in agronomic performance between the two phosphorus placements, except that side-band placed P treatment had higher plant density ($P < 0.001$) compared to seed-placed P in 2001 (**Figure 60**).

Summary: A number of significant yield differences (side-band less than mid-row in 2001, broadcast less than banded and AA less than urea in 2000), were noted. Treatment differences in agronomic variables in the other two years were relatively small and inconsistent; no doubt a reflection of the drought conditions.

Canola: Overall average yield was the highest in canola in 2000 (1.2 t ha^{-1}) (**Table 15**). Severe droughts resulted in yields for 2001 and 2002 that were only about 70% (0.9 t ha^{-1}) and 22% (0.3 t ha^{-1}) respectively, of yields in 2000.

Effect of N placement: Side-banded treatments tended to produce higher grain yield and straw yield compared to mid-row banded treatments for both fertilizer formulations in 2000 (**Figure 61**). Placement × form interactions were significant for plant density and kernel weight in this year. Side-banded treatments had significantly higher plant density for urea and lower kernel weight for AA compared to mid-row banded treatments, while no differences in density for AA or in kernel weight for urea were found (**Table 15**). In 2001, mid-row treatments had slightly higher grain yield but lower ($P < 0.05$) straw yield compared to side-band treatments. This contrasted with 2000, where the opposite occurred for grain yield. Early in the year, the side-band treatments appeared more vigorous than the mid-row band treatments. It is possible that sideband N was accessed earlier than mid-row N. This would lead to more vigorous growth that would deplete moisture reserves more rapidly, leaving less for seed development and filling. No treatment differences were found in 2002.

In most cases, there were no significant differences between broadcast urea and band urea treatments (**Figure 62**). Spring broadcast urea reduced yield slightly in 2000. Observations indicated that the spring broadcast treatment showed N deficiency symptoms early in the growing season of 2000.

Effect of N formulation: Yield was consistently higher for urea than for AA in 2000 (**Figure 63**). A similar difference was found for straw yield. Urea treatments had higher ($P < 0.05$) plant density for the side-banded placement, but not for the mid-row banded placement. In the other two years, all variables either did not differ significantly or the actual differences were too small to be of agronomic importance.

Effect of timing: There were no significant differences in agronomic performance between fall and spring N applications (**Figure 64**).

Effect of N rate: Canola yield and straw yield increased as fertilizer N rate increased in 2000 and 2001, although the magnitude of the responses was small in 2001 (**Figure 65**). Plant density tended to decrease in 2000, but increase in 2002 with increasing N. Plant densities, however, were considered to be adequately high and no differences in time to emergence were noted. Although the kernel weight was significantly reduced by increasing N, the actual differences were small.

Effect of P placement: There were no significant differences in agronomic performance between the two P placements (**Figure 66**).

Summary: A number of significant yield differences (mid-row less than side-band, broadcast less than banded, AA less than urea), were noted in 2000. Treatment differences in agronomic variables in the other two years were relatively small and inconsistent, likely a reflection of the drought conditions.

Flax: The overall average yield was the highest in 2000 (2.0 t ha^{-1}) (**Table 16**). Severe droughts resulted in only 1.3 t ha^{-1} in 2001 and 0.3 t ha^{-1} in 2002.

Effect of N placement: Side-band placed N slightly increased yield compared to mid-row band placed N in 2000 (**Figure 67**). This was clearly not related to plant density because mid-row treatments had significantly higher plant density than side-band treatments. There were no other significant differences in plant growth between the two placements. No significant differences in agronomic performance were observed in 2001 or 2002.

In 2000, both banded treatments had significantly higher yield compared to the broadcast treatment, which was attributed to higher plant density and kernel weight for side-banded and higher kernel weight for mid-row banded treatments (**Figure 68**). No significant differences between broadcast and banded treatments were found in 2001 or 2002.

Effect of N formulation: Urea treatments produced significantly higher grain yield compared to AA treatments in 2000, which was associated with a higher plant density (**Figure 69**). In 2001, urea treatments had lower straw yield than AA treatments for side-banded placement, not for mid-row banded placement (**Table 16**). Although urea treatments had higher plant density than AA treatments, overall plant densities for all treatments were considered adequate so as not to limit yield. No other differences in grain yield or agronomic performance were noted in either 2001 or 2002.

Effect of timing: Spring banded treatments produced significantly higher grain yield than fall banded treatments in 2000, which was possibly attributed to higher kernel weight rather than plant density (**Figure 70**). Actually, fall banded treatments had higher plant density in 2000 and 2001, although this did not translate into a difference in grain yield in 2001.

Effect of N rate: In 2000, grain yield responded linearly to N rate, but the magnitude of increase was reduced for treatments with N rates higher than the recommended level (**Figure 71**). In 2001, the yield increase was small after the first increment of N. In 2002, the severe drought prohibited any yield response to the increase of N. The response patterns of straw yield to N rate were similar to that of grain yield although not significant. Although there were significant responses of kernel weight to N rate, the actual changes were very small.

Effect of P placement: There were no significant differences in agronomic performance between the two P placements (**Figure 72**).

Summary: A number of significant yield differences (broadcast less than banded, AA less than urea), were noted in 2000. Treatment differences in agronomic variables in the other two years were relatively small and inconsistent.

4.2 Overall Summary: Yields and Yield Components

The weather, always a "wild card" in Saskatchewan, created rather challenging conditions during this three-year study. Precipitation ranged from above average precipitation at Swift Current and Indian Head in 2000, to a severe drought causing complete crop failure at Scott in 2002. This was both an advantage, in that we have results from our N management treatments over a wide range of environmental conditions, and a disadvantage in that the results vary widely and interpretation must carefully consider the context of the particular year and site. In this regard it should be noted that the results for the wheat crop at Star City in 2002, and all crops at Scott in 2002 were not considered in our overall conclusions.

Flax tended to be the least responsive to either N amount or management. There was a general increase in seed yield to the first increment of N added (30 kg ha^{-1} at Swift Current and Scott, 40 kg N ha^{-1} at Star City and Indian Head), but little or no response to higher rates. In fact at some sites and years yields actually decreased at the high N rate (90 kg ha^{-1} at Swift Current and Scott, 120 kg N ha^{-1} at Star City and Indian Head). Seed yields tended to be lower when flax received broadcast compared to banded urea in 3 of 11 site years, but the difference was only significant in 2 of those years. Similarly, seed yields tended to be lower when flax received fall banded rather than spring banded N in 6 of 11 site years, with the difference being significant in 3 of those years.

Wheat showed modest response to both N amount and management. Grain yields often increased up to the recommended rate (60 kg ha^{-1} at Swift Current and Scott; 80 kg N ha^{-1} at Star City and Indian Head), with strong responses up to the high N rate occurring in 2000 at both Star City and Scott. Wheat yield was higher on side-band compared to mid-row band in 2 of 10 site years. There was a weak trend for wheat to have lower grain yield on fall banded compared to spring banded N in 3 of 11 sites years, but the difference was only significant in 1 of those years. Grain yields were lower when urea was broadcast compared to banded in 5 of 11 site years, with the difference being significant in 3 of those instances.

Canola also showed modest responses to N amount and management. Grain yields often increased up to the recommended N rate, with strong responses up to the high N rate occurring in 2000 at both Star City and Scott. There was a weak trend for canola to have lower grain yield on fall banded compared to spring banded N in 5 of 11 sites years, but the difference was only significant in 1 of those years. Conversely, canola had higher grain yield on fall banded compared to spring banded N in 2 of 11 site years, with both instances being significant. Grain yields were lower when urea was broadcast compared to banded in 6 of 11 site years, but the difference was only significant in 2 of those instances. Seed-placed P increased seed yield on 5 of 11 sites years with 3 instances being significant.

When the results are view across crops but within sites, a few interesting patterns emerge. At Indian Head, canola yield was consistently higher when P was seed placed rather than side-band place, although the difference was only significant in one of the three years. As well, grain yields were higher from treatments receiving urea compared to AA in 5 of the 9 crop/site years, with 3 instances being significant. Lastly, canola yields were significantly higher in 2 of 3 years when N was applied in the fall rather than spring.

Only one relatively consistent trend emerged at Star City. Grain yields were lower when N was applied in the fall rather than in spring on 5 of 8 crop/site years. Similarly, only one trend emerged for the Scott site. Grain yields were higher on urea compared to AA treatments for all three crops in 2000, but this trend was not repeated in 2001 and all crops failed in 2002. At Swift Current, grain yields tended to be lower when urea was broadcast rather than banded in 7 of 9 crop/site years, with 3 instances being significant. Both canola and flax had lower yields in each of the three years when N was banded in the fall rather than in the spring, but the difference was only significant for flax in 2001. Wheat yields were also lower on the fall N treatments in 2002.

Considering grain yields over all sites, crops and years, the results from this study confirm that fall banded N and broadcasted urea are less efficient than their spring banded counterparts. Interestingly, urea appeared to provide slightly better yields at Indian Head, but AA and urea appeared to perform equally at the other three sites. This "lack of difference" between N-formulation is of some significance in two respects. Firstly, it suggests that side-band placement of AA is as effective as urea. Secondly, it has long been assumed that AA is not effective in the Swift Current area, but our results imply that AA is equal to urea in this region. Although plant densities tended to be lower on side-band compared to mid-row banded treatments, this was usually not translated into differences in grain yield. Our results suggest that side-band systems increase the potential for problems with seed-bed quality under either dry soil conditions or on wetter conditions in heavy clay soils. However, if dry conditions prevail during the first few weeks following seeding, access to N by the emerging crop may be more limited with the mid-row band placement. Overall, there was no significant difference between the two systems 84% of the time (27 of 32 the site/crop years considered here - crop failures were not included). Grain yield differences were more or less equally split between the two systems. Side-band had significantly higher grain yields in 3 of 32 site/crop years (about 9%), although there was a trend for higher yields on 2 other occasions ($P < 0.10$). Likewise, mid-row band tended to have significantly higher grain yields in 2 of 32 crop/site years (about 6%), and tended ($P<0.10$) towards higher yields on 2 other occasions.

4.3 Grain and Straw-N Concentrations and N Update

4.3.1 Grain N Concentrations

Placement of N in the side-row or mid-row position had limited effect on the final N concentration in the seed. Although a significant difference was observed in 10 of 32 crop-site years (**Tables 17** to **28**), six of those instances correspond to occurrences of a seed yield difference, and likely reflect a dilution effect (higher seed yield resulting in lower N concentration). For the remaining four occurrences, grain N concentration was higher on side-row compared mid-row banded N for flax at Swift Current in 2001 (**Table 19**) and Star City in 2002 (**Table 25**), and also for canola at Star City in 2000 and 2002 (**Table 24**).

Seed-N concentrations were significantly lower when urea was broadcast rather than banded in 4 of the 32 site-crop years. Three of those instances can be explained as yield dilution. The remaining instance occurred at Star City in 2000 on the flax crop (**Table 25**). In this case seed-N concentration was significantly higher on banded rather than broadcast urea treatments.

Seed-N concentration was higher on the fall versus spring applied N treatments on 7 of 32 site years, with 3 of those instances likely related to yield dilution (i.e. yields higher on spring applied N treatments). Seed-N concentration was higher on treatments receiving fall compared to spring applied N on 3 of the remaining 4 occurrences (wheat at Swift Current in 2000 (**Table 17**); and at Indian Head wheat (**Table 21**) and canola in 2002 (**Table 18**)). In the 4th instance (wheat at Star City in 2000 (**Table 23**)), seed-N concentration was higher on spring applied AA compared to fall applied AA (no differences on urea).

Lastly, and perhaps most interestingly, seed-N concentrations were lower on treatments receiving AA rather than urea in 7 of 32 site-crop years - with the reverse occurring on one occasion. There were 3 occasions when seed yield and seed-N concentrations were significantly higher on treatments receiving urea rather than AA. In the agronomy discussion we concluded that AA performed similarly to urea with respect to yield. Here we note a trend for seed-N to be lower on AA treatments.

In contrast to grain yield, grain N concentration consistently responded to N rate. On 30 of the 32 crop-site-year observations (4 excluded due to crop failure) there was a significant linear response, on 10 of those occasions the response could also be described as a quadratic response.

Summary for Grain-N Concentrations: Most of the significant treatment differences in seed-N concentration were likely related to the yield dilution effect. Apart from this however, there was still an indication of a weak trend for seed-N concentration to be higher on side-row compared mid-row banded N. Similarly, seed-N concentration tended to be lower on treatments receiving N in the form of AA rather than urea. There was a consistent trend for seed-N concentration to increase linearly as fertilizer-N rate increased. These observations are based upon the results of statistical differences. Further analysis would be required to determine if the difference in seed-N concentration was of economic importance.

Straw-N Concentrations: Numerous significant treatment differences were noted for straw-N concentration. However, closer inspection does not indicate any particular relationship between seed yield or seed-N concentration. When straw-N concentrations from side-band and mid-row band were compared, 8 of the 32 site-year combinations showed side-row having significantly higher N concentrations. At Indian Head in 2001 (**Table 21**), canola seed and straw yield were lower from side-row compared to mid-row, and straw-N concentration was significantly higher on the side-band compared to mid-row treatments. There were no other correspondences between a significant straw-N difference and a significant seed yield difference.

Similarly, there were 7 occurrences of straw-N concentration differences between spring broadcast and spring banded urea. In 4 instances N concentration was higher on the banded treatments and in 3 instances the reverse was true. There were only 2 instances where treatment differences were significant on straw-N and on seed yield. At Swift Current in 2001 (**Table 19**), flax straw-N concentration was higher on broadcast compared to banded urea, but seed yield was lower. Conversely, at Indian Head in 2001, both canola seed yield and straw-N concentration were lower on broadcast compared to banded urea treatments (**Table 21**).

There were 7 occurrences of higher straw-N concentration on treatments receiving urea compared AA. On three of those occasions there were also significant seed yield differences. Wheat and canola receiving AA compared to urea had lower straw-N and seed yield at Indian Head in 2000 (**Table 20** and **21**). Conversely, canola straw-N concentration was significantly lower on treatments receiving AA rather than urea, but seed yield was significantly higher.

Lastly, there were 2 occurrences of significant treatment differences on straw-N concentration for the fall versus spring banded N comparisons. For flax at Swift Current in 2001 (**Table 19**), N concentration was higher on fall band treatments, but seed yield was lower. Conversely, for canola at Star City in 2002 (**Table 24**), both straw-N and seed yield were lower on fall banded treatments.

Summary for Straw-N Concentrations: The lack of concurrence between seed-N or seed yield concentration leads us to conclude that differences in straw-N concentration on the side-band versus mid-row band, and the broadcast versus spring band comparison are of little material importance. There was a trend for straw-N concentrations to be lower on treatments receiving AA rather than urea, particularly at the Indian Head site. On at least a few of these occasions (3 out of 7) seed yield was also lower on AA compared to urea.

Nitrogen Uptake: Nitrogen uptake, expressed in terms of kilograms per hectare, is simply grain and straw yield multiplied by their respective N concentrations. Logically, unless there are large differences in N concentration, as yield increases so too will N uptake. It is of little surprise then that treatment differences in N uptake largely reflect grain and/or straw yield differences. Although each significant yield increase did not translate into a significant N uptake difference, the reverse was largely true. That is to say, nearly all the significant treatment differences in N uptake corresponded to a significant yield increase. There were only three exceptions. On flax at Star City in 2002 (**Table 25**), N uptake was lower on treatments receiving broadcast compared to mid-row banded urea. Also on flax in 2002, but at Indian Head (**Table 22**), N uptake was lower on treatments receiving fall banded compared to spring banded N. Lastly, on canola in 2001 at Scott (**Table 27**), N uptake was lower on treatments receiving N as AA rather than urea.

4.3.2 Available Soil Nitrogen

Nitrogen treatments were applied according to the experimental protocol. This meant that plots receiving 1.5x the recommended N rate in the 1st year, received the same (1.5x recommended N rate) in the 2nd and 3rd years of the study. Thus there was the potential for accumulations of soil N to occur on treatments receiving high compared to low N rates. In the 1st year, each crop was assigned to a specific area of the field and the N treatments were randomized within that crop area. In the 2nd year, the same N treatments were applied to the same plots, but the crops were rotated so that wheat was seeded into canola stubble, flax into wheat stubble, and canola into flax stubble. To check for indications of N accumulations, the same physical location needs to be monitored each year. Consequently, **Tables 29** to **40** present mean fall and spring soil available N (KCl extracTable nitrate + ammonium) as they relate to their physical location in the field. For example, **Table 29** presents soil available N across consecutive sampling times for each "fixed" N treatment at Swift Current. In this instance, the treatments were seeded to canola in the 1st year, wheat in the 2nd and flax in 3rd.

At Swift Current (**Tables 29** to **31**), mean soil available N was lowest in the fall of 2000, increased considerably by the fall of 2001 and then decreased to levels just slightly higher than the fall of 2000 by the fall of 2002. This pattern simply reflects N uptake patterns. Growing conditions were highly favorable in 2000 and N uptake was high (**Tables 17** to **19**). Drought conditions in 2001 resulted in poor crop growth and very limited N uptake. For example, mean N uptake fell from 131 kg N ha^{-1} in 2000 to 30.4 kg N ha^{-1} in 2001 for wheat receiving side-banded urea at the high (1.5x recommended) rate (**Table 17**). Crop yields and N uptake was modest in 2002, and soil available N decreased to levels only slightly higher than they were in 2000. There were no apparent trends in soil available N relating to timing, placement, or formulation of fertilizer-N. In the fall of 2001, soil available N increased linearly with increasing N rate, but this effect was no longer apparent by the fall of 2002.

Soil available N patterns were similar at Indian Head (**Tables 32** to **34**), mean soil available N was lowest in the fall of 2000, increased considerably on the wheat-flax-canola and canola-wheat-flax cropping areas by the fall of 2001 and then decreased to levels just slightly higher than the fall of 2000 by the fall of 2002. N uptake on wheat and particularly flax was considerably lower in 2001 then in 2000, which would explain the higher soil available N levels in the fall of 2001. N uptake on canola, however, was high in both 2000 and 2001 (overall mean of 125 and 121 kg ha^{-1} respectively (**Table 21**)), thus soil available N on the flax-canola-wheat (canola in 2001) remained quite low throughout the 3-year period. There were no consistent trends in soil available N relating to timing, placement, or formulation of fertilizer-N. Soil available N did tend to increase with increasing fertilizer rate (note the significant linear fit). Overall mean soil available N in the fall of 2002 was very similar to soil available N on the check (very low N) treatments. At least in the 0-30 cm depth there appeared to be no indication of significant N accumulations due to consecutive applications of high rates of N.

Scott experienced dry conditions in 2000 and 2001 and a complete crop failure in 2002. Consequently, N uptake was moderate in the in 2000 and 2001 and minimal in 2002 (**Tables 14** to **16**). Soil available N was quite low in 2000, increased considerably in 2001 and was very high in 2002 (**Table 38** to **40**). There were no apparent trends in soil available N relating to timing, placement or formulation, but the effect of N rate was significant in the fall of 2001.

At Star City, N uptake was reasonably high for all crops in 2000 and 2001 (**Tables 23** to **25**). In 2002, N uptake was quite high for canola, modest for flax and minimal for wheat (this crop failed in 2002). There was a general increase in soil available N from the fall of 2000 to the fall of 2002 (**Tables 35** to **37**). Understandably levels were particularly high for the wheat area in the fall of 2002, where crop N uptake had been minimal. Again, there were no apparent trends in soil available N relating to timing, placement or formulation, but the effect of N rate was significant in each of the three falls.

Summary: Available Soil N: Inter-annual differences in soil available N patterns could be largely explained by its inverse relationship with N uptake. When N uptake was limited due to drought conditions, soil available N tended to increase significantly. There were no consistent trends in soil available N relating to timing, placement or formulation. There was a trend for soil available N to increase with increasing fertilizer N rate, particularly in site-years with poor crop growth.

4.4 Nitrous Oxide Emissions

Estimated annual N2O loss tended to be highest from Star City followed closely by Swift Current then Scott and lowest from Indian Head. We expected emissions would be related to moisture deficits, and anticipated highest emissions from Star City, followed by Indian Head, Scott, and finally Swift Current. It is of considerable interest that Indian Head tended to have the lowest fluxes. At this time, we can only speculate about the reasons behind this outcome. The soils at Indian Head have a high clay content relative to the other three sites (**Table 2**). There is a general relationship between gross denitrification and soil texture. Under similar moisture regimes, soils with higher clay contents will tend to have higher gross denitrification. This could translate into higher N_2O emissions, however, soils with higher clay content also have higher water-filled pore space, and this could result in lower N_2O:N2 ratios (i.e. denitrification goes to completion). Thus, although gross denitrification may be higher, ultimately less N_2O may be emitted from the soil surface. Secondly, mineralization-immobilization rates and patterns are strongly influenced by soil texture. It may be that applied N is rapidly immobilized in the heavy clay soils of Indian Head, resulting in less available-N during periods when the potential for N_2O production is high.

In general, the inter-annual variability of N_2O loss reflected precipitation patterns. At Star City for example, average to above average precipitation during the 2000-2001 cycle resulted in N_2O losses ranging between 162 and 672 g N ha^{-1}. In the following much drier year, N_2O losses ranged between 7 and 25 g N ha^{-1}. A similar, but less pronounced pattern can be observed at the other three sites.

4.4.1 Swift Current

Nitrous oxide loss tended to be higher from treatments receiving fertilizer N compared to the check at the Swift Current location, but the increase was only statistically significant in two of the three years (**Tables 41** to **43**). During the first field season (May 2000-April 2001) between 40 and 80 percent of the N_2O emitted occurred during the frost-free period, while 90 to 100 percent of all losses occurred during the frost-free period of the second and third field seasons. Very low emissions during spring of the latter two years was likely related to the dry fall conditions and limited snowfall.

Nitrous oxide emissions were measured from three rates of urea (30, 60 and 90 kg N ha^{-1}) placed in the mid-row band position. Fertilizer N application rate did not significantly influence N_2O emissions during the 2002-2003 annual cycle (**Table 43**). Fertilizer N rate did significantly increase N_2O emissions during 2000-2001 and the 2001-2002 field cycles (**Tables 41** to **42**). Losses increased linearly with increasing N rate during the 2001-2002 cycle, but the proportion of fertilizer N lost as N_2O increased significantly at the higher N rates in the 2000-2001 cycle; as evidenced by the significant quadratic response (**Table 41**; **Figure 73**).

Statistical analysis indicated that N_2O emissions were higher from fall compared to spring banded N during the spring of 2002 and 2003. However, emissions were so low during both of these time periods that we attach no material importance to this observation. Conversely, emissions were significantly ($p<0.1$) lower from fall compared to spring banded N during the frost-free period of 2000 and 2001. On an annual basis, emissions were significantly ($p<0.1$) lower from fall compared to spring banded N only in year two of the study (**Table 42**). In view of the unusually dry spring conditions, we have limited confidence in the comparisons of N_2O emissions from fall versus spring applied nitrogen.

There was no indication that fertilizer N formulation (AA versus urea) had any significant influence on total N_2O emissions. Similarly, there were no significant differences in the emissions of N_2O from spring broadcast versus spring banded N. Banding N in a mid-row versus side-row position did appear to increase N_2O losses. Emissions were significantly higher from mid-row compared to side-row banded N in 2000 and 2001 during the frost-free period and when considered on an annual basis (**Tables 41** to **42**).

4.4.2 Scott

Fertilizer N applications tended to increase N_2O emissions, but the increase was only statistically significant during the spring thaw and frost-free period of 2002, and on an annual basis during the 2002-2003 cycle (**Tables 44** to **46**). During the first field cycle (May 2000-April 2001), between 5 and 70 percent of the N_2O emitted occurred during the frost-free period, while 67 to 96 percent of all losses occurred during the frost-free period of the second and third field cycles. Very low emissions during the spring of the latter two years was likely related to the dry fall conditions and limited snowfall.

Nitrous oxide emissions were measured from three rates of urea (30, 60 and 90 kg N ha ^{1}) placed in the mid-row band position. Fertilizer N application rate did not significantly influence N_2O emissions during the 2000-2001 annual cycle (**Table 44**); but did increase emissions significantly during the following two years (**Tables 45** and **46**). The increase in emissions was linear during the 2002-2003 cycle (**Table 46** and **Figure 74**). During the 2001-2002 cycle, estimated cumulative N_2O loss for the 60 kg N rate was lower than the 30 kg N rate (**Figure 74**), thus the response to N rate could not be described as linear or quadratic. Likely, this unusual result was simply a reflection of the extreme variability inherent to N_2O emissions.

There was no indication that fertilizer N formulation (AA versus urea) had any significant influence on total N_2O emissions. Similarly, there were no significant differences in the emissions of N_2O from fall versus spring banded N. It should be noted that we have limited confidence in this latter comparison in view of the unusually dry spring conditions.

There was a weak trend for N_2O emissions to be higher when N was banded in a mid-row versus side-row position. Estimated annual N_2O emissions were significantly higher from mid-row compared to side-row banded N during the 2002-2003 cycle, and also during the 2001 frost-free period (**Tables 45** and **46**).

4.4.3 Indian Head

Nitrous oxide loss tended to be higher from treatments receiving fertilizer N compared to the check at Indian Head. The increase was statistically significant on an annual basis, during the 2001-2002 and 2002-2003 cycles. Between 19 and 85 percent of the N_2O emitted occurred during the frost-free period, although in the final year emissions during the frost-free period represented 75 percent or more of the total. Similar to Swift Current and Scott, low emissions during spring thaw were likely related to the dry fall conditions and limited snowfall.

Nitrous oxide emissions were measured from three rates of urea (40, 80 and 120 kg N ha ^{1}) placed in the mid-row band position. On an annual basis, fertilizer N rate had a significant influence on N_2O emissions in the 2000-2001 cycle (**Table 47**). The 120 kg N ha ^{1} rate actually had lower cumulative emissions than the 80 kg N ha^{-1} rate (**Figure 75**). Likely, this unusual result is simply a reflection of the extreme variability inherent to N_2O emissions.

Statistical analysis indicated that N_2O emissions were higher from fall compared to spring banded N during the spring of 2001 and 2002. However, emissions were so low during the spring of 2002 that we attach no material importance to this observation. On an annual basis, there were no significant differences between fall and spring applied N. Fertilizer N formulation had no significant influence on N_2O at this site.

Emissions were higher from spring broadcast compared to spring banded in the 2001-2002 and the 2002-2003 annual cycles. In both instances the difference was highly significant ($p \leq 0.01$). Banding N in a mid-row versus side-row position significantly increased N_2O losses when the frost-free period of 2001 and 2002 and the spring period of 2002 and 2003 were considered independently, but differences were not significant when compared on an annual basis.

4.4.4 Star City

Nitrous oxide loss tended to be higher from treatments receiving fertilizer N applications compared to the check at Star City. The increase was statistically significant on an annual basis during the 2001-2002 and 2002-2003 cycles. Emissions from the spring period represented a larger proportion of the annual emissions at this site compared the other three sites. Although the proportion of emissions occurring during the frost-free period ranged as high as 92%, most of the treatments had values of 70% or less. During the 2000-2001 cycle the frost-free period represented 50% or less of the total annual emissions.

Nitrous oxide emissions were measured from three rates of urea (40, 80 and 120 kg N ha $^{-1}$) placed in the mid-row band position. Although emissions tended to increase linearly with increasing fertilizer rate, analysis did not show the influence of rate to be statistically significant in any year at this site.

Statistical analysis indicated that N_2O emissions were higher from fall compared to spring banded N during the spring of 2001 and 2003, as well as the frost-free period of 2002 and the 2002-2003 annual cycle. Emissions were higher from spring broadcast compared to spring banded urea during the frost-free period of 2002. This translated into higher emissions during the annual cycle. In both cases the differences were highly significant (**Table 52**).

Emissions were significantly higher from AA compared to urea during the 2000 frost-free period. This difference translated into significantly higher emission from AA compared to urea when compared on an annual basis (**Table 50**). Emissions were not higher from AA compared to urea in any other year or at any other site during this study.

Banding N in a mid-row versus side-row position significantly increased N_2O losses during the spring and frost-free period of 2001. The latter translated into significantly higher emissions from mid-row versus side-row N-placement for the 2001-2002 annual cycle. We don't attach any material significance to the difference observed during spring of 2001. There were no significant differences in fall soil available N (extractable nitrate + ammonia) or in total N uptake during 2000 for these two treatments.

4.4.5 Three Year Overview

Table 53 presents estimated N_2O loss summed across the three years of the study. Nitrogen applications significantly increased N_2O emissions compared to the check treatment at 3 of the 4 sites. The lack of significance at Star City can be explained by the unusually high loss on the check treatment during the spring of 2001. This resulted in a 3-year cumulative loss estimate for the check treatment that was equal or even somewhat higher than on some of the fertilized treatments.

Emissions were significantly higher from fall versus spring banded N at Star City, but not at any other site. Likewise, emissions from AA were significantly higher than urea at Star City, but not at any other location. Broadcasting rather than banding urea resulted in significantly higher 3-year cumulative estimates at Indian Head and Star City, while mid-row was significantly higher than side-row at Scott and Star City. N_2O loss showed a significant linear increase to fertilizer rate at 3 of 4 sites.

4.4.6 Effect of Crop and Phosphorus Placement

Nitrous oxide emissions are highly dependant upon the status of soil-water, soil-N ($NO_3^- + NH_4^+$) availability, and dissolved organic carbon. There can be considerable differences in water use and N-uptake patterns, root exudation and etc. between crop types. These differences could affect the magnitude and pattern of N_2O emissions. We monitored N_2O emissions on a common treatment (urea mid-row band 1.0x rate) during the growing season on each of the three test crops at each site to test for the possible influence of crop type on N_2O. Canola appeared to have no significant influence on N_2O emissions compared to flax or wheat, but flax had significantly higher emissions in 3 out of 12 site years (data not shown). The reader is cautioned that there was limited rigor in this comparison.

Phosphorus (P) was seed placed for all treatments except the side-row band, where P was banded with the N. An additional side-banded urea treatment (1.0x N rate) with seed placed P was included in this study to test for the potential confounding influence of P placed in the N band. Analysis of the data from these two treatments revealed no indication of a consistent treatment effect (data not shown).

4.4.7 Percentage of Fertilizer N lost as N_2O

Currently, N_2O emissions associated with N fertilizer utilization are estimated using a loss coefficient proposed by the Intergovernmental Panel on Climate Change (IPCC). This loss estimate is 1.25% of fertilizer N applied. Emissions of N_2O are the unavoidable consequence of naturally occurring soil-microbiological processes. It is assumed that fertilizer-N additions increase emissions above that which would occur naturally; therefore, the increase is considered an anthropogenic contribution.

We calculated the percentage of fertilizer-N lost as N_2O for the four sites. We assumed that the N_2O lost from the check (no N applied) treatment represented the background emissions. The difference between this background value and the amount of N_2O lost from treatments receiving N should represent the "fertilizer induced" N_2O emission. That difference divided by the total N applied as fertilizer (x 100) provides an estimate of the percentage of fertilizer N lost as N_2O. The percentage of fertilizer-N lost as N_2O-N for the four sites are presented in **Tables 54** to **57**.

The values calculated from our results are considerably lower than the value (1.25 %) currently used to estimate N_2O loss from nitrogen fertilizers. The highest estimated loss occurred on the urea broadcast treatment at Star City in the 2002-2003 annual cycle. For this particular treatment we estimated that about 1.0 % of fertilizer-N was lost as N_2O. Over 90% of all other estimates fell at or below 0.3 %, with an overall mean value of 0.2%.

Ideally, when N_2O flux measurements are taken from the chambers in the field, several samples should be collected over the collection period. This provides a time-course for calculating the concentration change occurring in the headspace of the chamber. For logistical reasons, we chose to estimate N_2O flux using a single time point, and assumed that the concentration change in the headspace was linear. Assuming linearity tends to under-estimate the true concentration change within the headspace. Consequently, our flux estimates may have been biased downwards. Work is currently underway to determine the probable bias that may have been introduced. Previous work conducted by the principle investigator found that this bias may be in the range of 30%. Even if we assume (to be very conservative) that our sampling methodology under-estimated N_2O flux by 50% (i.e. emissions were actually twice what we reported), our overall mean estimate of fertilizer-N lost N_2O would still only increase to 0.4%. In our opinion, our results clearly indicated that N_2O loss coefficients for fertilizer-N usage in western Canada are considerably lower than is currently assumed.

4.4.8 Conclusions: Nitrous Oxide Emissions

The results of this study verify that N_2O emissions increase with fertilizer N applications. They also suggest that, within the range of rates applied in this study, emissions increase in a linear fashion. In other words, the percentage of fertilizer-N lost as N_2O did not increase as fertilizer rates increased. The percentage of fertilizer-N lost as N_2O calculated from our results ranged between about zero (in drought conditions) and 1.0 %. However, the great majority of the percent-loss values calculated fell at or below 0.4 %. The overall mean value was 0.2 %. We indicated in the text of this report, that the sampling methodology employed may have led to a downward bias in our estimates. Even taking this into consideration, we feel the results clearly indicate a need to modify the current N_2O loss coefficient of 1.25 % that is applied to fertilizer-N use in western Canada.

We conclude that N_2O emissions are similar from AA compared to urea. Out of 12 site-years, there was only one occasion where N_2O emissions were significantly higher on treatments receiving AA compared to urea. There was a weak trend (4 of 12 site-years) for emissions to be higher when urea was broadcast rather than banded, and when fertilizer-N was mid-row rather than side-row (5 of 12 site years) banded. In the latter instance, the differences were generally not large in an absolute sense, and so of limited material importance. In general results from this study indicate that N_2O emissions are comparatively low from well-managed cropping systems in western Canada, and suggest that the specific N fertilizer system selected (side-row vs. mid-row, anhydrous vs. urea) is of less consequence than ensuring the optimal use of N fertilizer additions.

5. Energy Analysis

For an overview comparison of site, crop and year, the recommended nitrogen fertilizer rate (1.0 x N rate) of side-banded, spring applied, urea was selected. Gross energy yields and crop yields for this particular treatment are shown in **Table 58** for the year 2000, in **Table 59** for the year 2001, and in **Table 60** for 2002.

The yields of canola and flaxseed at the Indian Head and Star City research sites were substantially above the district averages in 2000, while wheat yields were slightly above the district average at Indian Head in 2000, and somewhat below the district average at the Star City site in 2000. The energy results reveal that canola gave much higher gross energy yields than wheat at both sites (**Table 58**). The gross energy yield of flaxseed was also considerably higher than for wheat at the Star City site in 2000.

Flaxseed yield at the Scott site was considerably above the district average in 2000, whereas wheat and canola yields were similar to district averages. The gross energy yield of flaxseed was substantially higher than that of wheat and canola in 2000 (**Table 58**). Wheat yield was very high at Swift Current in 2000, and this crop and site gave the highest gross energy yields of any crop at any site reflecting the very favorable growing conditions at Swift Current in that year (**Table 58**).

In 2001, the Star City, Scott, and Swift Current sites experienced severe drought conditions. Yields and gross energy production of all crops were much lower at these sites in 2001 compared to 2000 (**Table 59** compared to **Table 58**). Flaxseed gave the highest gross energy yields at these three sites in 2001 (**Table 59**).

In 2001, wheat yields at the Indian Head site were similar to wheat yields in 2000, whereas canola and flaxseed yields were substantially less than were obtained at this site in 2000 (**Table 59** compared to **Table 58**). As a result, gross energy yields of wheat and canola at this site were similar in 2001, and somewhat higher than the gross energy yield of flaxseed.

The very dry conditions experienced in 2001 were followed by much lower than average rainfall during April, May and the first few weeks in June of 2002. Indian Head and Swift Current received higher than average precipitation during the balance of the growing season. Wheat and canola yields were 74% and 90% of 10-year district averages at Swift Current, but flax yields recovered to 117% of the 10-year district average. Yields at Indian Head were 112%, 102% and 170% of 10-year district averages respectively for wheat, canola, and flax. Star City did not receive substantial rainfall until July, and suffered considerable hail damage at the same time. The wheat crop failed, the flax crop yielded 70% of the 10-year district average, while the canola crop recovered and yielded 107% of the10-year district average. Precipitation remained low at Scott throughout the growing season of 2002, resulting in a complete crop failure for all three crops. Canola at Star City provided the highest gross energy yields in 2002, followed closely by flax and then canola at Indian Head.

5.1 Effect of Drought on Measured Energy Performance Factors

Data from the Star City site for canola are shown in **Table 61**, and from the Swift Current site for spring wheat are shown in **Table 62**. Once again, data for the recommended rate of side-banded, spring applied urea is presented. The results indicate how drought can significantly reduce the overall energy performance of both canola and wheat production.

5.2 Treatment Effects on Gross and Net Energy Output

Net energy output is similar in concept to net economic returns. The output/input ratio (O/I) and grain/unit of input energy ratio (G/I) need to be considered in conjunction with net energy output, since use of the first two measurements by themselves can be misleading. For example, wheat production at Indian Head in 2002 without the use of fertilizer (**Table 71**) gave a high O/I and G/I. However, the gross energy yield was low and the net energy output was low also. The low net energy output, compared to the treatments employing fertilizer, suggests that the net economic return was likely low also for the no fertilizer treatment, even though the O/I and G/I values were the highest of all treatments.

5.2.1 Indian Head: Year 2000

The energy effects are presented in **Tables 63** to **65**.

Canola: The highest gross energy output and the highest net energy output, for any crop at any site, were achieved with canola produced with fall-banded urea (1.0 X N) (**Table 63**). Fall banding gave significantly higher gross and net energy outputs than spring banding ($P<0.06$) and urea gave significantly higher gross and net energy outputs than ammonia with fall banding.

Flax: Nitrogen fertilizer increased gross energy output significantly (**Table 64**). Increasing the rate of nitrogen fertilizer beyond 0.5 X N significantly decreased net energy output. The highest net energy output was achieved with side banding with 0.5 X N of urea in the spring.

Wheat: The first increment of nitrogen fertilizer (0.5 X N) significantly increased gross and net energy output (**Table 65**). While further increases in N fertilizer rate increased gross energy output, this effect was counterbalanced by the greater energy inputs, and net energy output did not increase or slightly decreased.

5.2.2 Indian Head: Year 2001

The energy effects are presented in **Tables 66** to **68**.

Canola: Fall banding gave significantly higher gross energy outputs and net energy outputs than spring banded treatments, with both urea and ammonia (**Table 66**). The highest net energy output (53,682 MJ ha^{-1}) was achieved with fall banding of urea. Although lower than the best net energy output achieved with canola in 2000, this output was still higher than the best net energy output achieved with either flax or wheat in 2001 at Indian Head. Nitrogen fertilization significantly increased energy output on the 0.5 X N treatment. Further increases in N rate did not improve energy performance. Mid-row banding with either urea or AA gave significantly higher gross energy output, net energy output, and O/I and G/I, compared to spring side banding (**Table 66**). Urea significantly outperformed ammonia in terms of all energy performance measurements. Urea side banding N and seed placing P fertilizer significantly improved energy output performance compared to placing both N and P in a side band.

Flax: Side-banding treatments significantly outperformed mid-row banding, especially for ammonia, in terms of gross energy output and net energy output (**Table 67**). The first increment of nitrogen fertilizer (0.5 X N) gave a significantly higher net energy output than the next increment of N. The highest net energy output (24,801 MJ ha^{-1}) was achieved when AA was side banded at the 1.5 X N rate. However, applying the 0.5 X N rate of AA gave almost as high a net energy output with a much lower input of energy.

Wheat: Side banding of N in the spring, compared to mid-row banding, significantly increased net energy output, as well as O/I and G/I (**Table 68**). The first increment of N fertilizer significantly improved net energy output compared to no N fertilizer. Broadcasting urea, compared to banding, led to significantly lower gross and net energy outputs.

5.2.3 Indian Head: Year 2002

Energy effects are presented in **Tables 69** to **71**.

Canola: Gross energy output ranged between 26,980 and 52,260 MJ ha^{-1} during the 2002 crop year (**Table 69**). Gross energy output was significantly increased by fertilizer addition, and by placing P with the seed rather than in the band for the side-row band 1.0 X N treatment (80 kg N ha^{-1}). Net energy output was significantly higher for AA treatments compared to urea treatments. The latter is a result of the lower energy inputs for AA, not to a difference in crop yield.

Flax: Gross energy output ranged between 39,813 and 53,750 MJ ha^{-1} during the 2002 crop year (**Table 70**). Gross energy output was significantly increased by fertilizer addition, but the significant response was limited to the first increment (40 kg N ha^{-1}) of

N. Gross and net energy output was significantly higher for spring banded compared to fall banded treatments.

Wheat: Gross energy output ranged between 31,881 and 41,512 MJ ha^{-1} during the 2002 crop year (**Table 71**). The first increment of nitrogen fertilizer significantly increased gross energy output. Net energy output was significantly higher for AA treatments compared to urea treatments, a result of the lower energy inputs for AA, not a difference in crop yield. Significantly higher crop yields on the side-row compared to mid-row banded N treatments resulted in significantly higher gross and net energy outputs. Similarly, lower yields on the treatments receiving fall applied N also had significantly lower net (but not gross) energy outputs compared to treatments receiving spring banded N.

5.2.4 Indian Head: Three Year Overview

Across crops and years, gross energy production (significant in 7 of 9 crop/site years) increased with the addition of N fertilizer. However, significant increases in gross energy production were generally constrained to the first increment of N added. Yields tended not to increase in proportion to the additional energy invested at higher rates of N fertilizer, thus significant increases in net energy production occurred infrequently (significant in 3 of 9 crop/site years), with significant decreases in net production being observed for flax in 2000 and 2002.

The energy required to produce and transport AA is substantially lower than that required for urea. All other things being equal, net energy production should be significantly higher on AA compared to urea treatments. At Indian Head, a trend towards higher grain yields on the urea treatments offset this inherent difference on 7 of 9 crop/site years. Yields were increased enough to show significantly higher gross energy outputs for urea compared to AA treatments on 4 of 9 crop/site years, and net energy production in 1 crop/site years.

Gross and net energy production was higher on treatments receiving spring compared to fall applied N on 2 crop/site years, but the reverse was true on 3 occasions. Similarly, gross and net energy production was higher on side-row compared to mid-row banded N on 2 occasions, but the reverse was true on 1 occasion.

When the means of all treatments are compared, canola provided the highest gross and net energy outputs and O/I ratios in 2000 and 2001, but the lowest in 2002 (**Table 72**). Flax provided the highest gross and net energy outputs and O/I ratios in 2002, the lowest in 2001 and was intermediate in 2000. Means of three years show canola having substantially higher gross and net energy outputs and O/I ratios compared to flax and wheat, with little difference between the latter two crops.

5.2.5 Star City: Year 2000

The energy effects are presented in **Tables 73** to **75**.

Canola: Canola gross and net outputs were significantly improved by application of N fertilizer, with the largest effect observed with the first increment of N fertilizer (0.5 X N) (**Table 73**). Ammonia had a larger effect than urea. The highest net energy output was achieved with side banding of ammonia at the 1.0 X N rate, although mid-row banding produced almost as high a net energy output. Fall banding with urea improved net energy output more than fall banding with ammonia. Urea side banding, coupled with seed placing P fertilizer, improved gross and net energy outputs more than placing both urea and P fertilizer in a side band.

Flax: The gross and net energy response of flax to N fertilization was small, although significant (**Table 74**). Increasing the N rate from 0.5 to 1.0 X N or to 1.5 X N significantly decreased net energy output, and O/I and G/I. Fall banding with ammonia (1.0 X N rate) gave significantly higher net energy output than fall banding with urea.

Wheat: Wheat was very responsive to N fertilizer and gross and net energy output increased significantly up to the highest N rate (1.5 X N) (**Table 75**). The form of N (urea or ammonia) did not significantly affect gross or net energy outputs. Placing P fertilizer with the seed gave higher gross and net energy outputs compared to placing P in the side band with urea fertilizer.

5.2.6 Star City: Year 2001

Energy effects are presented in **Tables 76** to **78**. Drought affected this site in 2001. Thus all energy performance measurements were poorer in 2001 compared to 2000 for all three crops.

Canola: Nitrogen fertilization improved gross and net energy yields and improved O/I and G/I (**Table 76**). The first increment of nitrogen improved gross and net energy outputs, while higher rates of N had variable effects on net energy output.

Flax: The lowest rate of N fertilizer (0.5 X N), applied in spring, increased gross energy output but had only minor effects on net energy output (**Table 77**). Ammonia, applied at the lowest N fertilizer rate in the spring, improved gross and net energy output and the I/O and G/I significantly. However, higher rates of ammonia and of urea tended to lower gross and net energy outputs significantly. Fall banding of N fertilizer gave significantly lower gross and net energy outputs than spring banding of N fertilizer. Flax gave the highest net energy output (best treatment conditions) of the three crops at Star City in 2001.

Wheat: Wheat had the lowest net energy output (best treatment conditions) of the three crops grown at this site in 2001 (**Table 78**). Spring banding of ammonia, at the lowest rate (0.5 X N), improved gross and net energy output. Higher rates of N tended to reduce net energy outputs. Fall banding of N resulted in significantly lower gross and net energy outputs than spring banding.

5.2.7 Star City: Year 2002

The energy effects are presented in **Tables 79** to **81**.

Canola: Gross energy output ranged between 16,242 and 56,398 MJ ha^{-1} during the 2002 crop year (**Table 79**). Canola responded significantly to N fertilizer application, with the first two increments of N fertilizer significantly increasing gross and net energy output. Gross and net energy outputs were significantly lower when N was applied in the fall compared to spring, and when urea was broadcast compared to banded.

Flax: Gross energy output ranged between 14,633 and 24,384 MJ ha^{-1} during the 2002 crop year (**Table 80**). Net energy production was significantly lower from urea compared to AA. Gross and net energy outputs were significantly lower when N was applied in the fall compared to the spring, and when urea was broadcast compared to banded.

Wheat: The wheat crop failed at Star City due to extreme environmental conditions.

5.2.8 Star City: Three Year Overview

Across crops and years, gross energy production (significant in 7 of 8 instances) increased with the addition of N fertilizer. Significant increases in gross energy production were generally constrained to the first increment of N for flax, but wheat and canola responded to all three increments in 2000, and canola to the first two increments in 2002. Yields did not increase in proportion to the additional energy invested at higher rates of N fertilizer on flax, resulting in significantly lower values of net energy production at higher rates of N. The reverse was true for canola in 2002 and wheat in 2000.

At Star City, a trend towards higher grain yields on the AA treatments resulted in lower gross energy production values for urea compared to AA on 3 of 8 occasions. Significantly higher net energy production on AA compared to urea was noted on 5 of 8 occasions, but in 2 instances this result was due to the inherently lower energy inputs of AA not to yield differences.

Gross energy production was higher on treatments receiving spring compared to fall applied N on 6 of 8 occasions, while net energy production was lower on the fall applied N treatments on 4 of 8 crop/site years.

When the means of all treatments are compared, canola provided the highest gross and net energy outputs and O/I ratios in 2000 and 2002, and second highest in 2001 (**Table 82**). Flax provided the highest gross and net energy outputs and O/I ratios in 2001, the second highest in 2000 and 2002. Means of three years show canola having substantially higher gross and net energy outputs and O/I ratios compared to flax, and flax having substantially higher gross and net energy outputs and O/I ratios compared to wheat. The rankings remain the same even if the comparisons are made on the mean of two years (wheat crop failed in 2002).

5.2.9 Swift Current: Year 2000

The energy effects are presented in **Tables 83** to **85**.

Canola: The first increment of N fertilizer increased gross and net energy outputs significantly (**Table 83**). Effects of further increases in N rate were variable between treatments, but not significant. The highest net energy output was achieved when AA was side-banded in the spring at the 1.5 X N rate.

Flax: Rate of N fertilizer or type or method of application in the spring did not significantly affect gross or net energy outputs, with the exception of spring broadcasting of urea fertilizer, which yielded higher gross and net energy outputs (**Table 84**).

Wheat: Wheat yields were high without N fertilizer (**Table 85**). N fertilizer did not significantly improve energy performance as measured by gross or net energy outputs. Wheat gave a higher gross and net energy output at this site than did canola or flax.

5.2.10 Swift Current: Year 2001

The energy effects are presented in **Tables 86** to **88** of **Appendix I**. Severe drought negatively affected the energy performance of all crops at this site in 2001.

Canola: Application of the first increment of N fertilizer, especially ammonia, tended to improve net energy output (**Table 86**). Placing P fertilizer with the seed, as distinguished from placing P fertilizer in a side band with the urea N fertilizer, significantly improved gross and net energy outputs.

Flax: Treatment with the lowest N rate of ammonia (0.5 X N) increased net output significantly (**Table 87**). Fall banding significantly lowered net energy output, compared to spring banding. The highest rate of spring banding (1.5 X N) significantly lowered net energy output.

Wheat: Treatment with N fertilizer significantly lowered net energy output during the drought conditions at this site in 2001 (**Table 88**). This effect became more pronounced as N fertilizer rate was increased. The effect of drought on energy performance indicators was very pronounced for this crop (compare **Table 85** and **Table 88**).

5.2.11 Swift Current: Year 2002

The energy effects are presented in **Tables 89** to **91**

Canola: Gross energy output ranged between 18,463 and 44,782 MJ ha^{-1} during the 2002 crop year (**Table 89**). The first two increments of N fertilizer increased gross and net energy outputs significantly. No other treatment effects were evident for canola at this site.

Flax: Gross energy output ranged between 17,329 and 34,451 MJ ha^{-1} during the 2002 crop year (**Table 90**). The first two increment of N fertilizer increased gross energy outputs significantly. No other treatment effects were evident for flax at this site.

Wheat: Gross energy output ranged between 13,023 and 34,293 MJ ha^{-1} during the 2002 crop year (**Table 91**). The first two increment of N fertilizer increased gross and net energy outputs significantly. Gross and net energy outputs were significantly higher from side-row compared to mid-row banded N, from spring compared to fall banded N, and from banded compared to broadcast urea.

5.2.12 Swift Current: Three Year Overview

Across crops and years, gross energy production (significant in 4 of 9 instances) increased with the addition of N fertilizer. Significant increases in gross energy production were generally constrained to the first increment of N except in 2002, when gross and net energy production was significantly increased by the first two increments.

Urea treatments had significantly lower net energy production on only 1 of 9 occasions, and were actually higher on urea compared to AA on 1 occasion, indicating that slightly higher yields on urea managed to offset the inherently lower net energy values for urea compare to AA. Gross energy production was higher on treatments receiving spring compared to fall applied N on 2 of 9 occasions. Gross energy production was lower on broadcast urea compare to banded urea on 2 crop/site years, but the reverse was true on 1 occasion.

When the means of all treatments are compared, canola provided the highest gross and net energy outputs and O/I ratios in 2001 and 2002, and second highest in 2000 (**Table 92**). Wheat provided the highest gross and net energy outputs and O/I ratios in 2000, but lowest in 2001 and 2002. The exceptional yield in 2000 resulted in a 3-year mean showing wheat having marginally higher gross and net energy outputs and O/I ratios compared to canola, with flax coming in a more distant third.

5.2.13 Scott: Year 2000

The energy effects are presented in **Tables 93** to **95**.

Canola: Canola responded significantly to N fertilizer application and the first increment of N fertilizer significantly increased gross and net output (**Table 93**). The second increment of N fertilizer had little effect on net energy output, but the third increment (1.5 X N) again significantly increased gross and net energy output. Side banding gave greater gross and net energy outputs than mid-row banding, and urea gave significantly higher gross and net energy outputs than ammonia, whether spring applied or fall applied.

Flax: Flax responded significantly to nitrogen fertilization and the first two increments (0.5 X N, 1.0 X N) significantly increased gross and net energy returns (**Table 94**). Urea tended to cause greater increases than ammonia in gross and net energy returns. Side banding in the spring produced higher gross and net energy returns than mid-row banding at the same N fertilizer rate. Fall banding gave lower gross and net energy returns than spring banding. Spring broadcast of urea resulted in lower gross and net energy returns than banding.

Wheat: All treatments significantly increased gross and net energy output (**Table 95**). Gross and net energy returns increased significantly with each increase in N fertilizer rate. Side banding N increased energy returns more than mid-row banding. Spring applied urea increased gross and net energy output more than ammonia. Fall banding of urea also increased gross and net energy output more than fall applied ammonia. Broadcasting urea in the spring gave lower energy returns than banded urea. Placing P fertilizer with the seed and banding urea gave higher gross and net energy output ($P<0.08$) than placing P and N in the side band.

5.2.14 Scott: Year 2001

The energy effects are presented in **Tables 96** to **98**. This site was severely affected by drought in 2001.

Canola: Mid-row banding was the only factor that increased net energy output in 2001, although the effect was small and more pronounced for ammonia than urea (**Table 96**).

Flax: Fertilizer N slightly increased gross energy output, but the effect was not large (**Table 97**). No factors significantly increased net energy output.

Wheat: Banding with ammonia in the spring significantly increased net energy output compared to banding with urea (**Table 98**). Ammonia was also superior to urea in increasing net energy returns from fall banding. Mid-row banding was superior to side banding for both urea and ammonia fertilizers. Increasing the N rate beyond 0.5 X N significantly reduced net energy output. Urea broadcast in the spring resulted in higher net energy output than spring banding.

5.2.15 Scott: Year 2002

The energy effects are presented in **Tables 99** to **101**, however the results cannot be considered meaningful as the site experienced a complete crop failure due to drought in 2002.

5.2.16 Scott: Two Year Overview

Gross and net energy outputs were more responsive to N applications at this site in the first year, increasing significantly to the first two or even three increments. However in the second year only flax showed a significant increase in gross energy as a result of N application. Gross and net energy production was greater when N was side-row compared to mid-row banded and for urea rather than AA treatments for all crops in 2000. In 2001, side-row had lower gross energy production compared to mid-row banded N on wheat. Broadcast urea had lower gross and net energy production compared to banded urea, as did fall compared to spring applied N on both wheat and flax in 2000.

When the means of all treatments are compared, flax provided the highest gross and net energy outputs and O/I ratios in both years (**Table 102**). Gross and net energy outputs and O/I ratios were slightly higher for canola than for wheat, but both were substantially lower than flax.

5.3 Output/Input and Grain/Unit of Input Energy Ratios: Overview

5.3.1 Fertilizer Placement and Timing

Broadcasting of urea fertilizer requires an additional field operation compared to side or mid-row banding, thus energy inputs are necessarily higher for this treatment. However this extra energy cost is not large and differences in O/I or G/I ratios are primarily determined by changes in yield or energy outputs. There were only 5 of 32 crop-site years when these differences were large enough to result in O/I and G/I ratios that were significantly lower on the broadcast compared to banded treatments.

Similarly, fall banding of fertilizer requires an additional field operation compared to spring banding. Consequently, energy inputs are necessarily higher, but the extra energy cost is not large and significant differences in O/I or G/I ratios are primarily determined by changes in yield or energy outputs. In 10 of 32 site-crop years these differences were large enough to result in O/I and G/I ratios that were significantly lower on the fall banded compared to spring banded treatments. There was 1 instance (canola at Indian Head in 2001) when the reverse occurred.

Energy inputs for mid-row and side-row band systems were considered to be equal. Small differences in the fuel and oil inputs are a reflection of grain yield differences resulting in more or less grain to harvest and haul. Consequently, any significant difference in O/I or G/I ratios between the two systems is exclusively related to grain yield. There were 9 instances when significant differences in O/I and G/I ratios occurred. In 5 of these instances side band systems had significantly higher O/I and G/I ratios, while the reverse was true on 4 occasions.

5.3.2 Fertilizer Rate

Fertilizer energy inputs constituted some 60 to 80 %, or more, of total energy inputs. Thus increasing N fertilizer rate necessarily results in statistically significant increases in total energy inputs. An inverse relationship between increasing fertilizer N rate and O/I and G/I ratios would also necessarily follow, unless there was a counterbalancing increase in grain yield. Yield response to N inputs was inconsistent, and in 26 out of 32 site/crop years it was not great enough to offset the increased energy investment. Wheat yields at Scott in 2000, and canola yields at Scott and Indian Head in 2000, and Swift Current and Scott in 2001, and Star City in 2002, did increase enough to offset the additional energy investment. The limited crop response to N fertilization was likely related, at least in part, to the drought conditions experienced in 2001 and the early part of 2002, as well as the fact that fertilizer N was not optimized according to soil test recommendations, but was applied according to a pre-determined experimental design.

5.3.3 Fertilizer Formulation

The energy cost of production and transporting urea to the farm is considerably more (75.63 MJ per kg of nitrogen) than the energy cost of production and transport of anhydrous ammonia (52.21 MJ per kg of nitrogen) (Nagy, 1999). Thus total energy inputs are significantly higher for all treatments utilizing urea compared AA. Clearly, O/I and G/I ratios will be similarly affected unless energy or grain outputs are substantially higher for AA compared to urea treatments. This did occur in 7 of 32 site years. In 4 cases (wheat at Scott, and canola at Scott and Indian Head in 2000 and canola at Star City in 2002) differences in yield and energy outputs just balanced the differences in energy input levels, resulting in no significant difference between urea and AA treatments. In the other three instances (canola at Scott, Swift Current and Indian Head in 2001), yield and energy output differentials were large enough that I/O and G/I ratios were significantly higher for urea compared to AA.

5.4 Conclusions: Energy Analysis

In this study, differences in total energy inputs were almost exclusively related to the energy costs of N fertilizer inputs. In most instances, there was limited crop response to increasing fertilizer N rate; therefore the best net energy values and input/output ratios were achieved with the first increment of N (0.5 x recommended rate), although gross energy outputs generally increased with increasing rates of N application. Spring broadcasting of urea, and fall application of urea or AA require additional field operations, thus the energy inputs are slightly higher than spring banded treatments. These higher energy inputs combined with lower crop yields resulted in significantly lower values for all of the energy indicators on the fall banded treatments about 30% of the time, but only on a few occasions (5 of 32) for the broadcast treatment. Energy inputs for the mid-row banding and side-row banding treatments were similar. Significant differences in energy production due to yield differences were noted in 9 of 32 sites years, but these were equally split in favor of mid-row and side-row banded systems. No clear conclusion can be drawn at this point regarding the energy efficiency of one system compared to another. Total energy inputs are higher for treatments utilizing urea compared AA, resulting in inherently lower net energy production and O/I ratios. In this study net energy production values were significantly lower on the urea treatments only about 30% of the time, suggesting a small yield advantage (higher gross energy output) to urea which offset the inherently higher energy inputs. However, the output/input ratios most often looked more favorable on the AA treatments.

6. Overall Conclusions

The weather, always a "wild card" in Saskatchewan, created rather challenging conditions during this three-year study. Precipitation ranged from above average precipitation at Swift Current and Indian Head in 2000, to a severe drought causing complete crop failure at Scott in 2002. This was both an advantage, in that we have results from our N management treatments over a wide range of environmental conditions, and a disadvantage in that the results vary widely and interpretation must carefully consider the context of the particular year and site. In this regard it should be noted that the results for the wheat crop at Star City in 2002, and all crops at Scott in 2002 were not considered in our overall conclusions.

Flax tended to be the least responsive to either N amount or management. There was a general increase in seed yield to the first increment of N added (30 kg ha^{-1} at Swift Current and Scott, 40 kg N ha^{-1} at Star City and Indian Head), but little or no response to higher rates. Wheat showed modest response to both N amount and management. Grain yields often increased up to the recommended rate (60 kg ha^{-1} at Swift Current and Scott; 80 kg N ha^{-1} at Star City and Indian Head), with strong responses up to the high N rate occurring in 2000 at both Star City and Scott. Canola also showed modest responses to N amount and management. Grain yields often increased up to the recommended N rate, with strong responses up to the high N rate occurring in 2000 at both Star City and Scott. Grain-N concentrations tended to increase linearly as fertilizer-N rate increased.

Considering grain yields over all sites, crops and years, the results from this study confirm that fall banded N and broadcasted urea are less efficient than their spring banded counterparts. Interestingly, urea appeared to provide slightly better yields at Indian Head, but AA and urea appeared to perform equally at the other three sites. This "lack of difference" between N-formulation is of some significance in two respects. Firstly, it suggests that side-band placement of AA is as effective as urea. Secondly, it has long been assumed that AA is not effective in the Swift Current area, but our results imply that AA is equal to urea in this region. There was, however, a weak trend for grain-N concentration to be lower on AA treatments compared to urea. Further analysis would be required to determine if the difference in seed-N concentration was enough to be of economic significance.

Although plant densities tended to be lower on side-band compared to mid-row banded treatments, this was usually not translated into differences in grain yield. Our results suggest that side-band systems increase the potential for problems with seed-bed quality under either dry soil conditions or on wetter conditions in heavy clay soils. However, if dry conditions prevail during the first few weeks following seeding, access to N by the emerging crop may be more limited with the mid-row band placement. Overall, there was no significant difference between the two systems 84% of the time. When they occurred, grain yield differences were more or less equally split between the two systems. There was also a weak trend for grain-N concentration to be higher on side-row compared mid-row banded N. Again, further analysis would be required to determine if the difference in seed-N concentration was enough to be of economic significance.

The results of this study verify that N_2O emissions increase with fertilizer-N applications. They also suggest that, within the range of rates applied in this study, emissions increase in a linear fashion. In other words, the percentage of fertilizer-N lost as N_2O did not increase as fertilizer rates increased. The great majority of the percent-loss values calculated fell at or below 0.4 %. The overall mean value was 0.2 %. Even taking into consideration the possibility that our sampling methodology may have introduced some downward bias in the flux estimates, we feel the results clearly indicate a need to modify the current N_2O loss coefficient of 1.25 % that is applied to fertilizer-N use in western Canada.

We conclude that N_2O emissions are similar from AA compared to urea. There was a weak trend for emissions to be higher when urea was broadcast rather than banded, and when fertilizer-N was mid-row rather than side-row banded. In the latter instance, the differences were generally not large in an absolute sense, and so likely of limited material importance. In general results from this study indicate that N_2O emissions are comparatively low from well-managed cropping systems in western Canada, and suggest that the specific N fertilizer system selected (side-row vs. mid-row, anhydrous vs. urea) is of less consequence than ensuring the optimal use of N fertilizer additions.

Differences in total energy inputs were almost exclusively related to the energy costs of N fertilizer inputs. In most instances, there was limited crop response to increasing fertilizer-N rate; therefore the best net energy values and input/output ratios were achieved with the first increment of N (0.5 x recommended rate), although gross energy outputs generally increased with increasing rates of N application. Spring broadcasting of urea, and fall application of urea or AA require additional field operations, thus the energy inputs are slightly higher than spring banded treatments. These higher energy inputs combined with lower crop yields resulted in significantly lower values for all of the energy indicators on the fall banded treatments about 30% of the time, but only on a few occasions for the broadcast treatment. There was no clear difference in energy efficiency energy efficiency between side-band and mid-row band systems. Total energy inputs are higher for treatments utilizing urea compared AA, resulting in inherently lower net energy production and O/I ratios. In this study net energy production values were significantly lower on the urea treatments only about 30% of the time, suggesting a small yield advantage (higher gross energy output) to urea which offset the inherently higher energy inputs. However, the output/input ratios most often looked more favorable on the AA treatments.

6.1 Acknowledgements

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6.2 References

Breitenbeck, G.A. and Bremner, J,M. 1986a. Effects of rate and depth of fertilizers on emission of nitrous oxide from soil fertilized with anhydrous ammonia. Biol. Fertil. Soils. 2: 201-204.

Breitenbeck, G.A. and Bremner, J,M. 1986b. Effects of various nitrogen fertilizers on emission of nitrous oxide from soils. Biol. Fertil. Soils. 2: 195-199.

Bremner, J,M., Breitenbeck, G.A. and Blackmer, A.M. 1981. Effect of anhydrous ammonia fertilization on emission of nitrous oxide from soils. J. Environ. Qual. 10:77-80.

Coxworth, E., Entz, M.H., Henry, S., Bamford, K.C., Schoofs, A., Ominski, P.D., Leduc, P. and Burton, G. 1995. Study of the Effects of Cropping and Tillage Systems on the Carbon Dioxide Released by Manufactured Inputs to Western Canadian Agriculture: Identification of Methods to Reduce Carbon Dioxide Emissions. Report to H.H. Janzen, Agriculture and Agri-Food Canada, Lethbridge, AB T1J 4B1. Three volumes.

Coxworth, E., Hultgreen, G. and Leduc, P. 1994. Net Carbon Balance Effects of Low Disturbance Seeding Systems on Fuel, Fertilizer, Herbicide and Machinery Usage in Western Canadian Agriculture. Report to TransAlta Utilities, Calgary, Alberta. 86 pp. Available from E. Coxworth, 1332 10th St. E., Saskatoon, SK S7H 0J3.

Lemke, R.L.; Izaurralde, R.C.; Malhi, S.S.; Arshad, M.A. and Nyborg, M. 1998. Nitrous oxide emissions from agricultural soils of the Boreal and Parkland regions of Alberta. Soil Sci. Soc. Am. J. 62: 1096-1102.

Lessard, R., P. Rochette, E. Topp, E. Pattey, R.L. Desjardins, and G. Beaumont. 1994. Methane and carbon dioxide fluxes from poorly drained adjacent cultivated and forest sites. Can. J. Soil Sci. 74:139-146.

Malhi, S.S. and Nyborg, M. 1991. Recovery of ^{15}N-labelled urea: Influence of zero tillage, and time and method of application. Fert. Res. 28: 263-269.

Nagy, C.N. 1999. Energy Coefficients for Agriculture Inputs in Western Canada. CSALE Working Paper Series #2. Centre for Studies in Agriculture, Law and the Environment. Colleges of Agriculture and Law, University of Saskatchewan, Saskatoon SK S7N 5A8.

SAS Institute Inc. 1996. SAS/STAT Software- Changes and Enhancements through Release 6.11. SAS Institute Inc. Cary, NC, USA. pp. 1094.

Saskatchewan Agriculture and Food., 1999. Farm machinery custom and rental rate guide 1999. Sustainable Production Branch, Saskatchewan Agriculture and Food, Regina, SK. 36 pp.

Zentner, R.P., Campbell, D.W., Campbell, C.A. and Read, D.W.L. 1984. Energy considerations of crop rotations in southwestern Saskatchewan. Can. J. Agric. Eng. 26: 25-29.

Zentner, R.P., Stumborg, M.A. and Campbell, C.A. 1989. Effects of crop rotations and fertilization on energy balance in typical production systems on the Canadian prairies. Ecosyst. Envir. 25: 217-232.

Zentner, R.P., McConkey, B.G., Stumborg, M.A., Campbell, C.A. and Selles, F. 1998. Energy performance of conservation tillage management for spring wheat production in the Brown soil zone. Can. J. Plant Sci. 78: 553-563.

Project Photos

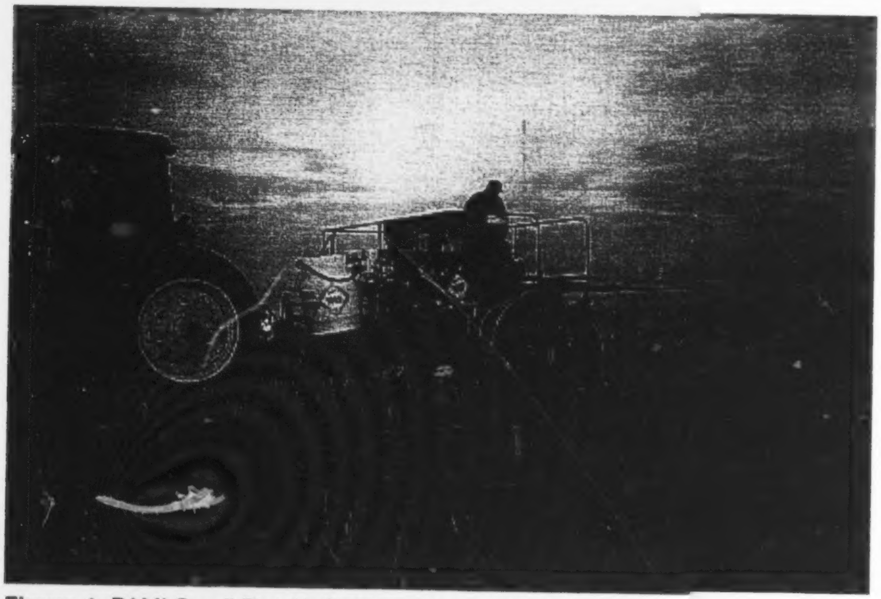

Figure 1. PAMI Small Plot Air Seeder with NH_3 System.

Figure 2. Bourgault Knives.

Figure 3. Flexi-Coil Stealth Side Banding Opener.

Figure 4. Flax Plots at Star City in 2000.

APPENDIX I

Appendix I

Table 1. Basic soil characteristics (0-30 cm) at four experimental sites in Saskatchewan.

Soil property	Star City	Indian Head	Swift current	Scott
pH	7.2	8.0	7.8	7.1
EC(S/cm)	0.2	0.2	0.2	0.2
Organic carbon(%)	1.3	1.5	0.7	1.4
Total carbon(%)	1.5	2.6	1.2	1.8
Total nitrogen(%)	0.12	0.17	0.12	0.11
Extractable K (μg/g)	185	380	200	153
NO_3-N (μg/g)	4.3	6.4	11.9	4.2
NH_4-N (μg/g)	2.9	3.7	2.6	21.4
Extractable P (μg/g)	1.9	3.7	3.5	4.2
% total sand	14.4	22.1	43.3	46.6
% total silt	33.0	8.3	32.1	28.0
% total clay	52.6	69.6	24.6	25.4

Table 2. Treatment combinations applied at each of the four sites. Treatments selected for trace gas monitoring are presented in bold type.

Treatment	N rate	P placement **
1. Urea + P side-band	0.5 x N rate	SB
2. Urea + P side band	**1.0 x N rate**	**SB**
3. Urea + P side-band	1.5 x N rate	SB
4. Urea mid-row-band	**0.5 x N rate**	**SP**
5. Urea mid-row band	**1.0 x N rate**	**SP**
6. Urea mid-row band	**1.5 x N rate**	**SP**
7. Urea fall band	**1.0 x N rate**	**SP**
8. Urea spring broadcast	**1.0 x N rate**	**SP**
9. NH_3 side-band	0.5 x N rate	SP
10. NH_3 side-band	**1.0 x N rate**	**SP**
11. NH_3 side-band	1.5 x N rate	SP
12. NH_3 mid-row band	0.5 x N rate	SP
13. NH_3 mid-row band	**1.0 x N rate**	**SP**
14. NH_3 mid-row band	1.5 x N rate	SP
15. NH_3 fall band	**1.0 x N rate**	**SP**
16. Check (side-band no N)	**no N**	**SP**
17. Urea side-band	**1.0 x N rate**	**SP**

** SB = side-banded with N; SP = seed-row placed

Table 3. Summary of energy parameters for outputs and inputs.

Output/Input Item	Energy Value		Units
Products			
Wheat	18.71		MJ kg^{-1}
Flax	25.98		MJ kg^{-1}
Canola	29.43		MJ kg^{-1}
Fuel			
Diesel	43.99		MJ L^{-1}
Gasoline	39.61		MJ L^{-1}
Lubricants	43.80		MJ L^{-1}
Fertilizers			
Urea -N	75.63		MJ kg^{-1}
Anhydrous Ammonia	52.21		MJ kg^{-1}
P_2O_5	9.53		MJ kg^{-1}
K_2O	9.85		MJ kg^{-1}
S	1.12		MJ kg^{-1}
Herbicides[1]			
2,4-D amine	98.00		MJ kg^{-1}
2,4-D ester	241.00		MJ kg^{-1}
Bromoxynil & MCPA ester (1:1)	335.00		MJ kg^{-1}
Clodinafop-propargyl	297.45		MJ kg^{-1}
Clopyralid & MCPA	221.28		MJ kg^{-1}
Dicamba & mecoprop & MCPA amine (5:5:22)	242.91		MJ kg^{-1}
Fluroxypyr & clopyralid & MCPA ester (18:5:28)	328.12		MJ kg^{-1}
Glyphosate	511.00		MJ kg^{-1}
Glufosinate ammonium	363.56		MJ kg^{-1}
Paraquat & diquat	511.83		MJ kg^{-1}
Sethoxydim	308.00		MJ kg^{-1}
Sethoxydim & clopyralid & MCPA ester (45:5:28)	529.28		MJ kg^{-1}
Surfactant	201.00		MJ L^{-1}
Tralkoxydim	313.77		MJ kg^{-1}
Machine Operations	Fuel & Oil	Overhead[2]	
Swather	103.70	17.30	MJ ha^{-1}
Spray	29.60	8.50	MJ ha^{-1}
Haul water	11.40	0.90	MJ ha^{-1}
Granular Applicator	85.90	4.90	MJ ha^{-1}
Zero-till air seeder	257.40	60.50	MJ ha^{-1}
Zero-till air seeder with NH_3	275.40	64.74	MJ ha^{-1}
Fall Banding	317.93	64.15	MJ ha^{-1}
Fall Banding with NH_3	339.44	68.64	MJ ha^{-1}
Combine & on-farm transport of grain - wheat[3]	357.29	46.82	MJ ha^{-1}
Combine & on-farm transport of grain - canola[3]	533.32	75.65	MJ ha^{-1}
Combine & on-farm transport of grain - flax[3]	599.07	86.41	MJ ha^{-1}
Grain storage[3]	-	31.30	MJ ha^{-1}
Miscelleaneous[4]	249.00	11.10	MJ ha^{-1}

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[1] ...Energy for all herbicides are shown per unit of active ingredient.

[2] Includes energy for repairs and energy expended in the manufacture, assembly and transport of machines to the farm gate.

[3] Shown for a yield of 2000 kg ha^{-1}.

[4] Includes energy for local transport of inputs and transport of products from the farm to initial point of sale.

Table 4. Mean monthly air temperature and precipitation (May-August) at four sites.

	Temperature (°C)				Precipitation (mm)			
	2000	2001	2002	Long term (30 yr)	2000	2001	2002	Long term (30 yr))
Swift Current								
May	18.9	12.2	8.5	11.0	65	23	22	48
June	13.8	15.0	15.7	15.6	54	32	144	68
July	19.1	19.7	19.6	18.2	127	63	73	53
August	18.4	20.9	15.5	17.9	13	3	102	41
Mean for temperature Sum for precipitation	15.6	17.0	14.8	15.7	259	121	341	210
Indian Head								
May	10.1	11.4	7.3	12.2	68	2	18	56
June	13.0	14.8	15.8	16.2	105	29	115	95
July	18.0	18.1	18.6	18.9	46	41	49	69
August	16.4	18.9	15.7	16.2	63	13	98	52
Mean for temperature Sum for precipitation	14.4	15.8	14.4	15.9	282	85	280	272
Star City								
May	9.0	12.0	6.8	10.8	43	46	4	44
June	13.5	14.4	16.7	15.6	74	35	54	69
July	17.5	18.8	19.6	17.4	111	73	94	75
August	16.2	19.2	15.9	16.4	49	22	91	54
Mean for temperature Sum for precipitation	14.1	16.1	14.8	15.1	277	175	243	241
Scott								
May	9.4	11.0	8.0	10.2	24	36	3	36
June	13.5	13.9	16.4	14.5	39	49	69	61
July	17.8	17.7	19.3	17.3	76	41	32	61
August	15.6	19.0	15.6	16.2	60	3	42	45
Mean for temperature Sum for precipitation	14.0	15.4	14.8	14.5	198	129	146	203

Table 5. Grain yield, straw yield and plant density in wheat at Swift Current.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.55	0.71	1.27	6.62	0.78	2.14	166	163	218
2) Side-banded urea with medium rate	4.21	0.90	1.78	6.07	0.78	2.23	176	136	201
3) Side-banded urea with high rate	3.31	0.70	1.79	6.79	0.85	2.28	155	172	222
4) Mid-row banded urea with low rate	3.55	0.74	1.23	6.12	0.84	1.81	153	176	204
5) Mid-row banded urea with medium rate	3.82	0.78	1.67	6.09	0.90	2.24	141	182	198
6) Mid-row banded urea with high rate	3.81	0.59	1.69	7.39	0.78	2.20	172	161	197
7) Fall banded urea with medium rate	3.80	0.69	1.24	5.99	0.85	2.10	155	157	180
8) Broadcasted urea with medium rate	3.59	0.67	1.13	6.61	0.83	2.03	183	170	168
9) Side-banded AA with low rate	3.64	0.59	1.29	6.33	0.78	2.17	190	134	213
10) Side-banded AA with medium rate	3.32	0.61	1.92	6.61	0.74	2.68	185	154	232
11) Side-banded AA with high rate	3.88	0.63	1.78	7.11	0.72	2.38	176	150	198
12) Mid-row banded AA with low rate	3.28	0.78	0.96	6.40	0.88	1.36	178	156	224
13) Mid-row banded AA with medium rate	3.15	0.71	1.51	7.09	0.92	1.75	178	174	226
14) Mid-row banded AA with high rate	4.32	0.70	1.45	7.10	0.91	2.47	164	166	184
15) Fall banded AA with medium rate	4.03	0.85	1.51	6.59	0.90	2.09	166	178	193
16) Very low N	3.89	0.76	0.79	5.81	0.78	1.54	182	176	210
17) Side-banded urea with medium rate + P	3.93	0.62	1.64	6.95	0.73	2.23	166	125	196
Mean	3.71	0.71	1.45	6.57	0.82	2.10	170	160	204
LSD (0.05)	1.13	0.24	0.45	1.64	0.22	0.64	31	41	37
Significance	NS	NS	***	NS	NS		NS	NS	NS

Table 6. Grain yield, straw yield and plant density in canola at Swift Current.

	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	1.56	0.75	1.12	7.43	2.00	3.46	63	58	45
2) Side-banded urea with medium rate	1.63	0.50	1.53	6.59	2.46	3.89	70	46	61
3) Side-banded urea with high rate	1.81	0.62	0.71	7.20	2.36	4.12	68	43	37
4) Mid-row banded urea with low rate	1.55	0.43	0.90	6.88	2.14	2.59	58	43	58
5) Mid-row banded urea with medium rate	1.91	0.67	1.24	7.50	2.19	3.63	76	49	42
6) Mid-row banded urea with high rate	1.86	0.78	1.30	7.23	2.30	3.93	62	55	67
7) Fall banded urea with medium rate	1.64	0.62	1.18	7.22	2.81	3.25	70	48	45
8) Broadcasted urea with medium rate	1.52	0.72	1.03	6.66	2.49	3.91	80	43	35
9) Side-banded AA with low rate	1.72	0.54	1.15	5.85	2.11	3.40	65	50	67
10) Side-banded AA with medium rate	1.72	0.76	1.19	6.35	2.12	3.07	54	42	49
11) Side-banded AA with high rate	1.80	0.94	1.13	7.24	2.70	4.03	72	47	67
12) Mid-row banded AA with low rate	1.56	0.54	0.85	6.43	2.21	2.45	52	54	61
13) Mid-row banded AA with medium rate	1.78	0.83	1.17	6.81	2.17	3.91	70	49	50
14) Mid-row banded AA with high rate	2.08	1.03	1.50	7.25	2.99	3.78	48	55	47
15) Fall banded AA with medium rate	1.66	0.78	1.07	6.29	2.71	3.43	59	41	29
16) Very low N	1.07	0.41	0.63	5.50	1.82	1.85	65	58	63
17) Side-banded urea with medium rate + P	1.62	0.82	1.31	6.25	2.13	2.71	62	32	51
Mean	1.68	0.69	1.12	6.75	2.34	3.38	64	48	51
LSD (0.05)	0.52	0.29	0.37	1.49	0.78	1.26	24	18	31
Significance	NS	**	***	NS	NS	*	NS	NS	NS

Table 7. Grain yield, straw yield and plant density in flax at Swift Current.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	1.74	0.61	1.15	3.87	1.36	1.58	494	379	455
2) Side-banded urea with medium rate	1.64	0.71	1.39	4.01	1.36	2.02	547	366	445
3) Side-banded urea with high rate	1.91	0.54	1.28	3.34	1.07	1.80	412	355	418
4) Mid-row banded urea with low rate	1.85	0.69	1.23	3.90	1.34	1.74	459	399	371
5) Mid-row banded urea with medium rate	1.65	0.94	1.32	3.86	1.44	2.22	394	457	425
6) Mid-row banded urea with high rate	1.96	0.58	1.23	3.82	1.18	1.73	419	414	326
7) Fall banded urea with medium rate	1.60	0.54	1.27	4.20	1.31	1.74	612	410	396
8) Broadcasted urea with medium rate	1.97	0.54	1.16	4.42	1.27	1.75	616	439	410
9) Side-banded AA with low rate	1.87	0.86	1.21	4.33	1.51	1.74	518	433	430
10) Side-banded AA with medium rate	1.90	0.71	1.16	4.32	1.31	1.50	544	477	383
11) Side-banded AA with high rate	1.82	0.54	1.13	4.42	1.18	1.66	441	348	376
12) Mid-row banded AA with low rate	1.61	0.79	1.04	3.84	1.57	1.45	484	495	434
13) Mid-row banded AA with medium rate	2.02	0.64	1.30	4.42	1.38	1.81	517	380	496
14) Mid-row banded AA with high rate	1.62	0.70	1.29	4.13	1.72	1.73	530	402	484
15) Fall banded AA with medium rate	1.75	0.65	1.06	4.35	1.28	1.76	701	417	357
16) Very low N	1.76	0.60	0.73	4.08	1.26	1.30	505	441	462
17) Side-banded urea with medium rate + P	1.90	0.62	1.03	4.12	1.18	1.63	427	333	390
Mean	1.80	0.66	1.17	4.08	1.34	1.72	507	408	415
LSD (0.05)	0.47	0.19	0.31	0.94	0.31	0.54	127	110	113
Significance	NS	**	*	NS	*	NS	***	NS	NS

Table 8. Grain yield, straw yield and plant density in wheat at Indian Head.

	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	2.23	2.03	2.28	7.51	3.45	3.61	255	164	250
2) Side-banded urea with medium rate	2.39	2.22	2.34	7.61	4.78	3.86	254	132	273
3) Side-banded urea with high rate	2.44	2.24	2.35	7.74	3.45	3.94	273	149	264
4) Mid-row banded urea with low rate	2.19	1.92	2.19	6.79	3.78	3.54	253	191	264
5) Mid-row banded urea with medium rate	2.28	2.09	2.23	5.44	3.62	3.65	217	193	268
6) Mid-row banded urea with high rate	2.25	2.04	2.26	6.01	3.87	4.24	235	187	209
7) Fall banded urea with medium rate	2.37	2.04	2.23	6.61	4.76	2.99	268	197	298
8) Broadcasted urea with medium rate	2.48	1.79	2.33	7.45	3.15	3.62	262	197	324
9) Side-banded AA with low rate	2.12	1.95	2.34	6.63	3.01	3.82	255	150	280
10) Side-banded AA with medium rate	2.19	1.99	2.34	6.89	3.54	3.91	245	120	306
11) Side-banded AA with high rate	2.20	1.97	2.44	7.52	2.83	3.94	245	136	272
12) Mid-row banded AA with low rate	1.94	1.75	2.05	6.03	3.86	3.58	241	217	270
13) Mid-row banded AA with medium rate	2.29	1.88	2.24	7.28	2.36	3.65	257	219	286
14) Mid-row banded AA with high rate	2.37	2.03	2.29	6.86	3.72	3.90	248	228	270
15) Fall banded AA with medium rate	2.21	1.95	2.09	5.90	3.54	3.93	272	218	297
16) Very low N	1.36	1.58	1.84	5.59	2.78	2.46	240	159	268
17) Side-banded urea with medium rate + P	2.46	1.97	2.28	7.24	4.21	4.07	260	128	273
Mean	2.22	1.97	2.24	6.77	3.57	3.69	252	175	275
LSD (0.05)	0.29	0.35	0.27	1.66	1.90	0.96	32	57	49
Significance	***	NS	*	NS	NS	NS	NS	***	*

Table 9. Grain yield, straw yield and plant density in canola at Indian Head.

	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	2.23	1.31	1.20	5.12	5.07	4.94	95	29	57
2) Side-banded urea with medium rate	2.17	1.31	0.94	4.16	8.47	4.71	90	25	76
3) Side-banded urea with high rate	2.73	1.21	1.53	5.34	6.15	3.91	88	23	63
4) Mid-row banded urea with low rate	2.10	1.90	0.99	4.65	5.35	5.28	109	45	54
5) Mid-row banded urea with medium rate	2.74	2.02	1.36	5.26	4.55	5.86	109	40	61
6) Mid-row banded urea with high rate	2.98	2.02	1.29	3.72	5.99	5.66	86	48	39
7) Fall banded urea with medium rate	3.46	2.25	1.30	4.44	6.94	4.50	104	68	51
8) Broadcasted urea with medium rate	2.06	1.98	1.36	3.60	6.38	5.11	95	49	53
9) Side-banded AA with low rate	2.36	0.60	1.08	5.38	5.63	4.70	102	10	63
10) Side-banded AA with medium rate	2.34	0.77	1.57	3.79	7.04	4.48	105	14	61
11) Side-banded AA with high rate	2.95	0.69	1.65	4.83	7.10	5.84	84	7	59
12) Mid-row banded AA with low rate	2.05	1.58	1.04	4.72	5.87	4.01	100	51	81
13) Mid-row banded AA with medium rate	2.19	1.89	1.40	5.04	5.53	5.84	96	52	67
14) Mid-row banded AA with high rate	2.23	1.85	1.48	5.14	7.25	4.90	98	38	74
15) Fall banded AA with medium rate	2.49	2.03	1.31	4.53	6.38	4.20	99	62	62
16) Very low N	1.84	1.06	0.92	4.91	5.55	3.03	96	26	74
17) Side-banded urea with medium rate + P	3.06	1.57	1.78	4.92	10.09	5.28	83	29	51
Mean	2.47	1.53	1.31	4.68	6.43	4.84	96	36	61
LSD (0.05)	1.27	0.38	0.45	2.80	5.66	1.74	24	20	21
Significance	NS	***	**	NS	NS	NS	NS	***	*

Table 10. Grain yield, straw yield and plant density in flax at Indian Head.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	1.71	1.23	1.90	5.79	2.46	3.45	584	247	436
2) Side-banded urea with medium rate	1.63	1.14	1.91	6.13	2.73	3.77	590	265	437
3) Side-banded urea with high rate	1.58	1.23	2.13	6.19	2.65	3.62	579	220	364
4) Mid-row banded urea with low rate	1.70	1.25	2.05	6.25	2.12	3.99	661	435	450
5) Mid-row banded urea with medium rate	1.68	1.22	2.03	6.22	2.42	3.96	670	416	393
6) Mid-row banded urea with high rate	1.63	1.22	2.09	5.92	2.63	3.99	666	403	365
7) Fall banded urea with medium rate	1.61	1.13	1.86	6.06	2.60	4.03	638	421	407
8) Broadcasted urea with medium rate	1.68	1.15	2.06	6.64	2.65	3.70	675	360	428
9) Side-banded AA with low rate	1.62	1.25	2.01	5.74	3.01	4.32	605	324	420
10) Side-banded AA with medium rate	1.53	1.24	1.92	6.46	2.90	3.98	581	293	442
11) Side-banded AA with high rate	1.51	1.42	1.94	7.29	3.15	4.23	537	251	399
12) Mid-row banded AA with low rate	1.61	1.20	2.08	5.85	2.74	4.21	737	417	494
13) Mid-row banded AA with medium rate	1.60	0.96	2.06	6.56	2.24	4.21	648	377	498
14) Mid-row banded AA with high rate	1.63	1.12	2.00	6.12	2.32	3.73	682	368	489
15) Fall banded AA with medium rate	1.68	1.29	1.82	5.75	2.67	3.43	638	426	495
16) Very low N	1.47	1.08	1.60	6.70	2.89	3.53	613	392	515
17) Side-banded urea with medium rate + P	1.52	1.23	1.84	7.75	3.13	4.02	489	220	439
Mean	1.61	1.20	1.96	6.32	2.67	3.89	623	343	440
LSD (0.05)	0.19	0.27	0.25	1.28	1.03	0.72	100	90	86
Significance	NS	NS	*	NS	NS	NS	**	***	*

Table 11. Grain yield, straw yield and plant density in wheat at Star City.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	2.05	0.92	0.35	4.71	3.68	0.84	289	265	269
2) Side-banded urea with medium rate	2.27	1.01	0.35	5.63	3.99	0.96	274	285	217
3) Side-banded urea with high rate	2.52	1.17	0.39	5.31	3.53	1.41	277	257	246
4) Mid-row banded urea with low rate	2.13	0.88	0.21	3.64	4.07	1.10	294	310	289
5) Mid-row banded urea with medium rate	2.45	0.94	0.25	4.00	4.68	0.94	294	262	290
6) Mid-row banded urea with high rate	2.76	0.98	0.34	4.50	4.34	0.98	282	259	221
7) Fall banded urea with medium rate	2.48	0.89	0.36	5.37	4.11	1.12	315	272	306
8) Broadcasted urea with medium rate	2.42	0.97	0.15	5.33	4.15	0.80	278	275	255
9) Side-banded AA with low rate	1.90	1.03	0.21	4.75	3.42	1.02	279	272	273
10) Side-banded AA with medium rate	2.46	1.09	0.27	5.64	4.07	1.22	270	277	288
11) Side-banded AA with high rate	2.56	1.07	0.28	5.92	3.68	1.09	262	264	280
12) Mid-row banded AA with low rate	1.92	1.14	0.24	4.27	3.71	1.37	281	277	301
13) Mid-row banded AA with medium rate	2.26	1.06	0.23	5.64	4.17	1.29	300	296	299
14) Mid-row banded AA with high rate	2.68	1.13	0.26	5.00	4.26	1.18	318	302	310
15) Fall banded AA with medium rate	2.24	0.77	0.23	4.73	3.60	1.22	285	291	281
16) Very low N	1.22	0.76	0.21	2.87	2.89	0.89	296	263	286
17) Side-banded urea with medium rate + P	2.47	1.03	0.25	5.33	4.25	0.81	276	248	287
Mean	2.28	0.99	0.27	4.86	3.92	1.07	286	275	276
LSD (0.05)	0.30	0.29	0.18	1.12	0.74	0.42	43	65	44
Significance	***	NS	NS	***	**	NS	NS	NS	**

Table 12. Grain yield, straw yield and plant density in canola at Star City.

	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	2.50	0.75	1.39	5.27	4.22	4.56	120	60	59
2) Side-banded urea with medium rate	2.44	0.84	1.83	6.64	5.03	6.09	103	68	55
3) Side-banded urea with high rate	2.39	0.85	1.77	6.15	5.05	4.62	103	72	54
4) Mid-row banded urea with low rate	2.29	0.67	1.29	5.08	4.09	3.51	117	59	58
5) Mid-row banded urea with medium rate	2.12	0.67	1.63	6.26	4.39	5.71	106	62	53
6) Mid-row banded urea with high rate	2.77	0.87	1.59	5.59	5.20	4.68	105	58	59
7) Fall banded urea with medium rate	2.60	0.77	1.57	5.98	4.42	4.71	100	50	42
8) Broadcasted urea with medium rate	2.56	0.72	1.31	5.08	4.65	5.49	101	60	39
9) Side-banded AA with low rate	2.25	0.54	1.16	5.11	4.13	4.50	110	64	45
10) Side-banded AA with medium rate	2.76	0.77	1.72	5.89	4.73	5.65	109	51	49
11) Side-banded AA with high rate	2.69	0.84	1.77	7.36	4.73	6.98	103	51	41
12) Mid-row banded AA with low rate	2.44	0.65	1.26	4.77	3.36	3.85	122	59	51
13) Mid-row banded AA with medium rate	2.75	0.64	1.70	5.11	4.71	5.09	117	58	48
14) Mid-row banded AA with high rate	2.80	0.75	1.92	4.90	5.32	5.43	127	54	61
15) Fall banded AA with medium rate	2.28	0.72	1.47	4.94	4.73	4.38	105	63	32
16) Very low N	1.81	0.45	0.56	3.68	2.62	2.48	108	56	45
17) Side-banded urea with medium rate + P	2.77	0.74	1.61	5.98	4.46	5.02	105	64	48
Mean	2.48	0.72	1.50	5.52	4.46	4.87	109	59	49
LSD (0.05)	0.27	0.20	0.25	1.34	1.17	1.56	21	16	15
Significance	***	**	***	***	**	***	NS	NS	*

Table 13. Grain yield, straw yield and plant density in flax at Star City.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	1.98	1.30	0.74	3.17	5.13	1.85	505	591	495
2) Side-banded urea with medium rate	1.94	1.22	0.90	3.85	4.77	1.82	445	533	548
3) Side-banded urea with high rate	1.94	1.00	0.91	4.11	4.70	1.93	454	502	473
4) Mid-row banded urea with low rate	1.96	1.24	0.90	3.24	4.81	2.09	467	586	434
5) Mid-row banded urea with medium rate	1.87	1.15	0.88	3.16	5.46	2.59	426	538	456
6) Mid-row banded urea with high rate	1.88	1.08	0.74	3.52	4.71	2.30	474	607	435
7) Fall banded urea with medium rate	1.90	1.02	0.67	3.47	4.16	1.26	410	508	465
8) Broadcasted urea with medium rate	1.85	1.20	1.00	4.01	4.82	1.82	454	563	479
9) Side-banded AA with low rate	1.95	1.40	0.89	3.70	5.33	1.74	480	577	478
10) Side-banded AA with medium rate	1.98	1.19	0.92	3.70	4.90	1.86	483	469	446
11) Side-banded AA with high rate	1.94	1.23	0.73	3.98	4.54	1.78	495	456	516
12) Mid-row banded AA with low rate	1.95	1.38	0.87	2.90	5.13	1.87	443	557	479
13) Mid-row banded AA with medium rate	1.88	1.23	0.89	3.37	4.69	2.23	527	523	473
14) Mid-row banded AA with high rate	1.99	1.26	0.91	3.41	4.89	2.52	472	591	443
15) Fall banded AA with medium rate	1.97	1.11	0.63	3.55	4.98	1.28	456	596	447
16) Very low N	1.79	1.12	0.72	2.62	4.64	1.53	412	635	527
17) Side-banded urea with medium rate + P	1.94	0.99	0.86	3.84	4.70	2.05	447	509	459
Mean	1.92	1.18	0.83	3.51	4.84	1.91	462	549	474
LSD (0.05)	0.13	0.19	0.20	0.76	1.02	0.53	73	76	107
Significance	NS	***	*	*	NS	***	NS	***	NS

Table 14. Grain yield, straw yield and plant density in wheat at Scott.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	1.89	1.49	0.22	2.40	1.51	0.48	241	274	133
2) Side-banded urea with medium rate	2.48	1.39	0.19	2.88	1.90	0.51	210	310	130
3) Side-banded urea with high rate	3.18	1.21	0.19	3.10	1.35	0.48	216	277	153
4) Mid-row banded urea with low rate	1.73	1.55	0.19	1.78	1.42	0.52	242	285	156
5) Mid-row banded urea with medium rate	2.62	1.42	0.19	2.26	1.29	0.50	255	289	172
6) Mid-row banded urea with high rate	2.77	1.53	0.16	2.56	1.57	0.49	223	275	128
7) Fall banded urea with medium rate	2.72	1.32	0.18	3.78	1.50	0.54	236	259	183
8) Broadcasted urea with medium rate	2.03	1.57	0.11	2.71	1.85	0.48	246	283	154
9) Side-banded AA with low rate	1.54	1.39	0.22	2.60	1.16	0.51	243	277	110
10) Side-banded AA with medium rate	1.96	1.48	0.18	2.82	1.34	0.48	219	287	117
11) Side-banded AA with high rate	2.97	1.26	0.17	4.01	1.15	0.41	258	256	120
12) Mid-row banded AA with low rate	1.30	1.72	0.17	1.66	1.32	0.55	242	279	166
13) Mid-row banded AA with medium rate	1.86	1.49	0.13	2.52	1.69	0.50	232	275	170
14) Mid-row banded AA with high rate	2.13	1.79	0.14	2.48	2.09	0.48	247	276	156
15) Fall banded AA with medium rate	2.05	1.58	0.16	2.56	1.65	0.56	270	284	186
16) Very low N	0.88	1.34	0.24	1.74	1.14	0.60	255	281	133
17) Side-banded urea with medium rate + P	2.68	1.51	0.20	2.53	1.55	0.44	220	254	142
Mean	2.16	1.47	0.18	2.61	1.50	0.50	238	278	147
LSD (0.05)	0.24	0.34	0.08	1.07	0.67	0.11	36	30	42
Significance	***	NS	NS	**	NS	NS	NS	NS	**

Table 15. Grain yield, straw yield and plant density in canola at Scott.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	1.32	0.78	0.18	3.68	2.63	2.21	66	46	30
2) Side-banded urea with medium rate	1.37	0.80	0.21	4.41	2.67	2.31	64	60	25
3) Side-banded urea with high rate	1.67	0.97	0.23	5.81	2.86	2.54	60	58	25
4) Mid-row banded urea with low rate	1.21	0.77	0.31	3.70	2.43	2.27	62	74	28
5) Mid-row banded urea with medium rate	1.37	0.91	0.30	4.59	2.59	1.84	39	67	23
6) Mid-row banded urea with high rate	1.53	0.93	0.27	4.63	2.32	2.44	54	57	29
7) Fall banded urea with medium rate	1.43	0.90	0.29	4.11	2.89	2.79	50	65	34
8) Broadcasted urea with medium rate	1.26	0.91	0.26	3.50	2.41	2.69	53	64	22
9) Side-banded AA with low rate	1.00	0.72	0.31	3.94	2.07	2.14	50	73	18
10) Side-banded AA with medium rate	1.11	0.74	0.28	4.68	3.06	1.98	56	51	34
11) Side-banded AA with high rate	1.57	0.90	0.40	4.61	2.45	2.01	51	58	22
12) Mid-row banded AA with low rate	0.89	0.82	0.32	2.94	1.91	2.35	49	59	24
13) Mid-row banded AA with medium rate	0.94	0.95	0.25	2.59	2.02	1.78	53	57	38
14) Mid-row banded AA with high rate	1.21	1.06	0.24	4.25	2.52	2.21	59	53	33
15) Fall banded AA with medium rate	1.13	0.84	0.27	4.35	2.85	2.31	50	67	23
16) Very low N	0.68	0.75	0.27	2.82	1.60	2.05	66	50	16
17) Side-banded urea with medium rate + P	1.41	0.98	0.26	4.51	2.56	2.81	53	47	17
Mean	1.24	0.87	0.27	4.07	2.46	2.28	55	59	26
LSD (0.05)	0.32	0.23	0.12	1.46	0.77	1.08	14	20	16
Significance	***	NS	NS	**	*	NS	*	NS	NS

Table 16. Grain yield, straw yield and plant density in flax at Scott.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Plant density (m^{-2})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	1.96	1.30	0.26	2.64	1.82	0.63	255	510	170
2) Side-banded urea with medium rate	2.31	1.28	0.25	2.27	1.74	0.78	315	415	147
3) Side-banded urea with high rate	2.43	1.30	0.25	2.53	1.64	0.63	297	510	151
4) Mid-row banded urea with low rate	1.75	1.51	0.28	2.23	1.98	0.69	355	441	217
5) Mid-row banded urea with medium rate	2.21	1.20	0.19	3.25	1.87	0.75	260	476	179
6) Mid-row banded urea with high rate	2.40	1.52	0.26	2.30	2.26	0.60	351	451	123
7) Fall banded urea with medium rate	2.11	1.40	0.22	3.00	2.28	0.51	340	499	164
8) Broadcasted urea with medium rate	1.91	1.35	0.25	2.86	2.01	0.66	267	497	183
9) Side-banded AA with low rate	1.74	1.20	0.25	2.50	1.81	0.54	241	477	192
10) Side-banded AA with medium rate	2.19	1.40	0.24	2.61	2.33	0.39	236	454	178
11) Side-banded AA with high rate	2.36	1.39	0.28	3.06	2.00	0.54	220	406	185
12) Mid-row banded AA with low rate	1.66	1.34	0.23	1.70	1.84	0.63	307	403	161
13) Mid-row banded AA with medium rate	1.99	1.40	0.20	1.87	1.96	0.70	268	397	206
14) Mid-row banded AA with high rate	2.10	1.47	0.26	2.65	2.11	0.87	237	409	233
15) Fall banded AA with medium rate	1.84	1.24	0.19	2.59	2.14	0.75	386	522	181
16) Very low N	1.21	1.06	0.30	2.40	1.63	0.71	215	455	157
17) Side-banded urea with medium rate + P	2.24	1.12	0.27	2.80	1.75	0.53	244	429	139
Mean	2.02	1.32	0.25	2.54	1.95	0.64	282	456	174
LSD (0.05)	0.22	0.38	0.08	1.09	0.48	0.39	96	93	86
Significance	***	NS	NS	NS	NS	NS	**	NS	NS

Table 17. Grain and straw-N concentration and total N uptake in wheat at Swift Current.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	2.65	3.23	2.25	0.29	0.60	0.28	116.0	27.3	34.3
2) Side-banded urea with medium rate	2.85	3.26	2.67	0.32	0.59	0.43	139.3	29.1	57.2
3) Side-banded urea with high rate	3.15	3.45	2.79	0.39	0.76	0.45	131.0	30.4	60.2
4) Mid-row banded urea with low rate	2.62	3.37	2.35	0.30	0.66	0.28	114.5	30.5	34.1
5) Mid-row banded urea with medium	2.78	3.37	2.67	0.28	0.63	0.42	123.6	32.0	53.7
6) Mid-row banded urea with high rate	3.09	3.50	2.83	0.38	0.79	0.45	147.5	26.8	57.4
7) Fall banded urea with medium rate	2.94	3.45	2.78	0.30	0.82	0.44	130.1	30.6	43.5
8) Broadcasted urea with medium rate	2.83	3.42	2.62	0.26	0.78	0.38	119.7	29.2	37.3
9) Side-banded AA with low rate	2.60	3.43	2.35	0.24	0.74	0.25	110.8	25.9	35.8
10) Side-banded AA with medium rate	2.54	3.48	2.46	0.20	0.80	0.36	98.1	27.5	56.6
11) Side-banded AA with high rate	2.86	3.50	2.67	0.26	0.76	0.38	129.8	27.7	56.4
12) Mid-row banded AA with low rate	2.64	3.03	2.37	0.23	0.50	0.30	103.1	27.6	26.6
13) Mid-row banded AA with medium	2.66	3.45	2.53	0.27	0.73	0.33	104.4	31.1	44.2
14) Mid-row banded AA with high rate	2.99	3.49	2.72	0.38	0.75	0.40	157.6	30.8	49.2
15) Fall banded AA with medium rate	3.00	3.44	2.66	0.32	0.70	0.40	141.1	29.8	47.5
16) Very low N	2.62	2.86	2.51	0.20	0.48	0.31	115.0	25.2	24.4
17) Side-banded urea with medium rate	3.02	3.26	2.66	0.34	0.70	0.33	143.9	25.1	50.8
Mean	2.81	3.35	2.58	0.29	0.69	0.36	125.0	28.6	45.2
LSD (0.05)	0.33	0.25	0.12	0.15	0.14	0.10	51.2	6.4	12.6
Significance	**	***	***	NS	***	***	NS	NS	***
Contrast									
Side vs. mid-row	NS	NS	NS	NS	NS	NS	NS	NS	*
Broadcast vs. banding	NS	NS	NS	NS	**	NS	NS	NS	**
Urea vs. AA	0.10	NS	**	0.06	NS[1]	0.08	NS	NS	NS
Fall vs. spring	**	NS	**	NS	0.07	NS	NS	NS	NS
Orthogonal contrasts for N rate				NS	NS	NS	NS	NS	NS
Linear	**	***	***	*	***	***	NS	NS	***
Quadratic	NS	*	***	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	***	NS	NS	*	NS	NS	**

Table 18. Grain and straw-N concentration and total N uptake in canola at Swift Current.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.10	4.22	3.42	0.36	0.52	0.36	75.4	42.7	51.5
2) Side-banded urea with medium rate	3.21	4.97	3.79	0.45	1.14	0.47	82.4	51.8	75.9
3) Side-banded urea with high rate	3.81	5.11	4.34	0.58	1.23	0.66	111.0	60.6	57.8
4) Mid-row banded urea with low rate	3.20	4.14	3.24	0.41	0.54	0.26	82.2	29.6	37.7
5) Mid-row banded urea with medium	3.32	4.83	3.64	0.50	0.96	0.39	101.1	52.9	59.1
6) Mid-row banded urea with high rate	3.74	5.01	4.04	0.51	1.05	0.56	106.4	63.3	74.5
7) Fall banded urea with medium rate	3.33	4.91	3.92	0.43	0.91	0.50	85.9	56.7	62.9
8) Broadcasted urea with medium rate	3.50	4.64	3.64	0.42	0.66	0.40	80.8	49.3	54.2
9) Side-banded AA with low rate	3.41	4.38	3.25	0.40	0.64	0.35	82.5	37.1	50.2
10) Side-banded AA with medium rate	3.46	4.63	3.47	0.44	0.67	0.40	87.3	47.1	53.3
11) Side-banded AA with high rate	3.67	4.73	3.99	0.46	0.67	0.45	99.0	61.7	63.3
12) Mid-row banded AA with low rate	3.10	4.05	3.00	0.38	0.51	0.22	73.2	33.5	31.3
13) Mid-row banded AA with medium rate	3.30	4.63	3.44	0.39	0.56	0.37	86.1	49.8	54.7
14) Mid-row banded AA with high rate	3.51	4.51	3.91	0.46	0.60	0.53	107.7	63.2	78.9
15) Fall banded AA with medium rate	3.28	4.52	3.90	0.38	0.67	0.46	78.5	52.4	58.0
16) Very low N	2.91	4.26	3.09	0.33	0.50	0.29	49.4	26.6	25.3
17) Side-banded urea with medium rate +	3.37	4.69	3.92	0.48	0.85	0.59	84.4	55.5	68.2
Mean	3.37	4.60	3.65	0.43	0.75	0.43	86.7	49.0	56.3
LSD (0.05)	0.33	0.51	0.49	0.13	0.25	0.18	26.5	15.0	19.9
Significance	**	**	***	*	***	***	**	***	***
Contrast									
Side vs. mid-row	NS	NS	NS	NS	*	0.09	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	***	NS	NS	NS	NS
Urea vs. AA	NS	0.09	*	NS	***	0.07	NS	NS	NS
Fall vs. spring	NS	NS	*	NS	NS	NS	NS	NS	NS
Orthogonal contrasts for N rate			NS	NS	NS	NS	NS	NS	NS
Linear	***	***	***	**	**	***	***	***	***
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	*	NS	NS	NS	NS	NS	NS	NS

Table 19. Grain and straw-N concentration and total N uptake in flax at Swift Current.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.75	4.64	2.25	0.34	0.70	0.28	78.2	27.3	38.0
2) Side-banded urea with medium rate	3.94	4.72	2.67	0.35	0.56	0.43	78.6	29.1	40.9
3) Side-banded urea with high rate	4.08	4.65	2.79	0.42	0.66	0.45	92.1	30.4	32.3
4) Mid-row banded urea with low rate	3.77	4.45	2.35	0.32	0.52	0.28	82.4	30.5	37.1
5) Mid-row banded urea with medium	3.96	4.38	2.67	0.39	0.51	0.42	80.4	32.0	48.6
6) Mid-row banded urea with high rate	4.14	4.69	2.83	0.44	0.78	0.45	97.4	26.8	36.3
7) Fall banded urea with medium rate	3.87	4.75	2.78	0.38	0.78	0.44	78.2	30.6	35.7
8) Broadcasted urea with medium rate	3.81	4.65	2.62	0.34	0.83	0.38	89.8	29.2	35.6
9) Side-banded AA with low rate	3.66	4.37	2.35	0.28	0.42	0.25	80.9	25.9	43.6
10) Side-banded AA with medium rate	3.72	4.51	2.46	0.31	0.55	0.36	84.2	27.5	38.6
11) Side-banded AA with high rate	3.64	4.76	2.67	0.33	0.73	0.38	81.4	27.7	34.2
12) Mid-row banded AA with low rate	3.55	3.98	2.37	0.34	0.31	0.30	70.3	27.6	36.4
13) Mid-row banded AA with medium rate	3.83	4.44	2.53	0.35	0.68	0.33	92.8	31.1	37.6
14) Mid-row banded AA with high rate	3.77	4.66	2.72	0.44	0.65	0.40	78.5	30.8	43.9
15) Fall banded AA with medium rate	3.77	4.73	2.66	0.38	0.80	0.40	82.9	29.8	40.8
16) Very low N	3.66	3.82	2.51	0.32	0.54	0.31	77.3	25.2	29.0
17) Side-banded urea with medium rate +	3.93	4.58	2.66	0.35	0.66	0.33	88.7	25.1	35.7
Mean	3.81	4.52	2.58	0.36	0.63	0.36	83.2	28.6	37.9
LSD (0.05)	0.32	0.35	0.26	0.06	0.29	0.13	21.8	9.2	14.7
Significance	*	***	***	***	*	*	NS	*	***
Contrast									
Side vs. mid-row	NS	*	NS	**	NS	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	*	NS	NS	*	NS
Urea vs. AA	***	0.09	NS	**	NS	NS	NS	NS	NS
Fall vs. spring	NS	*	NS	NS	*	NS	NS	NS	NS
Orthogonal contrasts for N rate									
Linear	*	***	**	**	0.09	**	NS	*	***
Quadratic	NS	0.06	NS	NS	NS	NS	NS	**	**
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 20. Grain and straw-N concentration and total N uptake in wheat at Indian Head.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	2.91	2.80	2.64	0.45	0.45	0.43	99.6	72.5	75.4
2) Side-banded urea with medium rate	2.94	2.89	2.78	0.45	0.49	0.44	105.3	87.4	82.0
3) Side-banded urea with high rate	3.00	2.89	2.81	0.58	0.51	0.44	118.2	81.9	83.1
4) Mid-row banded urea with low rate	2.94	2.61	2.56	0.41	0.44	0.39	93.6	67.1	70.0
5) Mid-row banded urea with medium	2.93	2.80	2.76	0.44	0.46	0.39	91.1	74.7	76.1
6) Mid-row banded urea with high rate	2.94	2.83	2.81	0.49	0.50	0.42	95.5	77.1	81.2
7) Fall banded urea with medium rate	3.02	2.89	2.83	0.49	0.52	0.37	103.4	83.1	74.3
8) Broadcasted urea with medium rate	2.94	2.65	2.77	0.41	0.44	0.40	103.8	61.6	78.9
9) Side-banded AA with low rate	2.88	2.76	2.62	0.35	0.52	0.37	84.8	69.7	75.4
10) Side-banded AA with medium rate	2.85	2.77	2.75	0.41	0.45	0.41	90.3	71.3	80.8
11) Side-banded AA with high rate	3.06	2.90	2.83	0.58	0.57	0.42	110.4	72.6	85.4
12) Mid-row banded AA with low rate	2.85	2.49	2.50	0.36	0.39	0.36	77.0	59.1	64.1
13) Mid-row banded AA with medium rate	2.95	2.64	2.71	0.37	0.40	0.38	95.5	58.8	74.4
14) Mid-row banded AA with high rate	2.93	2.66	2.80	0.44	0.43	0.42	99.1	70.1	80.5
15) Fall banded AA with medium rate	3.01	2.79	2.79	0.41	0.48	0.41	90.8	71.4	74.4
16) Very low N	2.80	2.60	2.43	0.38	0.36	0.31	59.1	51.0	52.4
17) Side-banded urea with medium rate +	2.99	2.95	2.78	0.50	0.56	0.39	110.4	81.2	79.5
Mean	2.94	2.76	2.72	0.44	0.47	0.40	95.8	71.2	75.7
LSD (0.05)	0.21	0.14	0.09	0.10	0.09	0.07	18.9	15.6	10.0
Significance	NS	***	***	***	***	*	***	**	***
Contrast									
Side vs. mid-row	NS	***	*	*	**	0.08	*	*	**
Broadcast vs. banding	NS	**	NS	NS	NS	NS	NS	**	NS
Urea vs. AA	NS	**	NS	*	NS	0.08	0.07	**	NS
Fall vs. spring	NS	NS	*	NS	NS	NS	NS	NS	NS
Orthogonal contrasts for N rate			NS	NS	NS	NS	NS	NS	NS
Linear	*	**	***	***	***	***	***	***	***
Quadratic	NS	NS	NS	NS	NS	NS	0.06	NS	***
Cubic	NS	NS	NS	NS	0.07	NS	NS	NS	NS

Table 21. Grain and straw-N concentration and total N uptake in canola at Indian Head.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.74	3.87	3.80	0.70	0.85	0.43	118.7	89.8	66.2
2) Side-banded urea with medium rate	3.71	4.05	4.01	0.77	1.12	0.50	111.9	137.7	61.4
3) Side-banded urea with high rate	3.89	4.22	3.99	0.83	1.41	0.58	151.8	132.0	83.7
4) Mid-row banded urea with low rate	3.54	4.04	3.80	0.62	0.73	0.45	101.8	115.9	62.0
5) Mid-row banded urea with medium	3.78	4.05	4.01	0.68	0.95	0.52	141.0	125.7	84.5
6) Mid-row banded urea with high rate	3.79	4.10	4.08	0.72	0.79	0.55	140.4	128.8	84.2
7) Fall banded urea with medium rate	3.92	3.98	4.02	0.83	0.74	0.54	173.8	143.0	76.2
8) Broadcasted urea with medium rate	3.68	3.96	3.94	0.80	0.67	0.53	106.5	119.5	80.5
9) Side-banded AA with low rate	3.70	4.02	3.62	0.61	1.27	0.42	121.1	95.4	58.7
10) Side-banded AA with medium rate	3.59	4.21	3.84	0.58	1.37	0.48	105.4	131.6	82.2
11) Side-banded AA with high rate	3.75	4.23	4.13	0.72	1.77	0.51	145.4	161.6	98.0
12) Mid-row banded AA with low rate	3.67	3.72	3.70	0.67	0.51	0.40	109.2	89.9	54.4
13) Mid-row banded AA with medium rate	3.60	3.85	3.90	0.59	0.56	0.42	109.0	104.5	79.0
14) Mid-row banded AA with high rate	3.61	4.03	4.00	0.65	0.77	0.49	115.8	126.2	83.0
15) Fall banded AA with medium rate	3.59	4.11	3.89	0.64	0.66	0.49	113.5	125.0	71.4
16) Very low N	3.78	3.60	3.56	0.75	0.63	0.38	107.0	69.4	44.2
17) Side-banded urea with medium rate +	3.90	4.17	4.09	0.72	1.03	0.50	156.3	168.5	98.7
Mean	3.72	4.01	3.90	0.70	0.93	0.48	125.2	121.4	74.6
LSD (0.05)	0.27	0.24	0.20	0.15	0.25	0.08	56.4	62.7	19.0
Significance	NS	***	***	*	***	***	NS	NS	***
Contrast									
Side vs. mid-row	NS	**[1]	NS	NS	***	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	**	NS	NS	NS	NS
Urea vs. AA	NS	NS	0.06	*	NS	**	NS	NS	NS
Fall vs. spring	NS	NS	NS	*	*	NS	NS	NS	NS
Orthogonal contrasts for N rate	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear	NS	***	***	NS	**	***	NS	**	***
Quadratic	NS	NS	NS	*	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 22. Grain and straw-N concentration and total N uptake in flax at Indian Head.

Treatment	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.60	3.90	3.88	0.67	0.48	0.64	101.4	59.7	96.2
2) Side-banded urea with medium rate	3.75	4.08	3.93	0.85	0.52	0.53	112.6	61.0	95.7
3) Side-banded urea with high rate	3.94	4.02	3.92	0.91	0.52	0.68	118.1	63.1	107.6
4) Mid-row banded urea with low rate	3.66	3.70	3.77	0.72	0.57	0.58	107.3	58.6	99.2
5) Mid-row banded urea with medium	3.71	3.88	3.95	0.80	0.53	0.56	112.9	60.2	102.5
6) Mid-row banded urea with high rate	3.78	3.92	3.92	0.85	0.54	0.68	111.7	61.9	109.2
7) Fall banded urea with medium rate	3.77	4.02	4.01	0.80	0.59	0.55	109.0	60.1	89.2
8) Broadcasted urea with medium rate	3.80	3.97	3.92	0.71	0.50	0.58	111.4	58.6	102.6
9) Side-banded AA with low rate	3.47	3.63	3.84	0.63	0.45	0.57	92.7	58.8	101.8
10) Side-banded AA with medium rate	3.74	3.85	3.96	0.83	0.54	0.64	110.9	62.3	100.6
11) Side-banded AA with high rate	3.87	3.96	3.96	0.90	0.56	0.56	123.6	74.5	100.7
12) Mid-row banded AA with low rate	3.49	3.63	3.72	0.61	0.57	0.49	91.6	59.3	97.7
13) Mid-row banded AA with medium rate	3.65	3.96	3.91	0.68	0.62	0.54	103.1	51.4	102.7
14) Mid-row banded AA with high rate	3.69	4.05	3.97	0.72	0.63	0.48	104.6	59.9	97.4
15) Fall banded AA with medium rate	3.67	4.09	3.95	0.71	0.57	0.53	102.2	67.7	90.1
16) Very low N	3.39	3.39	3.53	0.59	0.51	0.58	89.0	51.2	77.0
17) Side-banded urea with medium rate +	3.83	3.90	3.98	0.81	0.49	0.57	120.8	63.3	95.6
Mean	3.69	3.88	3.89	0.75	0.54	0.57	107.2	60.7	98.0
LSD (0.05)	0.18	0.27	0.17	0.13	0.10	0.18	16.9	12.5	13.3
Significance	***	***	***	***	*	NS	**	NS	**
Contrast									
Side vs. mid-row	0.06	NS	NS	*	**	NS	NS	0.07	NS
Broadcast vs. banding	NS	NS	NS	*	NS	NS	NS	NS	NS
Urea vs. AA	*	NS	NS	*	0.09	0.07	0.06	NS	NS
Fall vs. spring	NS	NS	NS	NS	NS	NS	NS	NS	*
Orthogonal contrasts for N rate									
Linear	***	***	***	***	NS	NS	***	**	***
Quadratic	NS	*	***	NS	NS	NS	NS	NS	**
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 23. Grain and straw-N concentration and total N uptake in wheat at Star City.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	2.57	3.60	3.82	0.57	1.41	1.80	79.3	84.7	28.3
2) Side-banded urea with medium rate	2.67	3.64	3.83	0.56	1.54	1.77	91.8	97.5	30.2
3) Side-banded urea with high rate	2.89	3.63	3.81	0.55	1.53	1.82	102.2	97.1	41.0
4) Mid-row banded urea with low rate	2.56	3.49	3.97	0.54	1.26	1.82	74.3	81.8	28.1
5) Mid-row banded urea with medium rate	2.64	3.68	3.87	0.57	1.40	1.80	87.7	100.0	26.7
6) Mid-row banded urea with high rate	2.78	3.72	3.84	0.52	1.52	1.96	99.6	102.5	32.1
7) Fall banded urea with medium rate	2.68	3.76	3.86	0.45	1.60	1.90	90.7	99.3	35.3
8) Broadcasted urea with medium rate	2.59	3.68	3.97	0.54	1.39	2.09	91.9	92.7	22.9
9) Side-banded AA with low rate	2.62	3.38	3.93	0.53	1.17	1.79	74.8	74.8	26.6
10) Side-banded AA with medium rate	2.79	3.62	3.93	0.52	1.42	1.89	98.0	97.4	33.3
11) Side-banded AA with high rate	2.94	3.66	3.88	0.57	1.56	1.89	108.9	96.6	31.0
12) Mid-row banded AA with low rate	2.59	3.40	3.89	0.48	1.18	1.71	70.1	82.7	32.3
13) Mid-row banded AA with medium rate	2.69	3.62	3.93	0.49	1.29	1.89	88.0	92.2	33.2
14) Mid-row banded AA with high rate	2.83	3.72	3.95	0.57	1.46	1.88	104.5	103.9	32.7
15) Fall banded AA with medium rate	2.58	3.69	3.92	0.51	1.48	1.78	81.9	82.0	30.7
16) Very low N	2.62	3.14	3.82	0.53	1.02	1.67	47.3	52.9	23.1
17) Side-banded urea with medium rate + P	2.64	3.66	3.87	0.54	1.47	1.93	94.0	99.7	25.3
Mean	2.69	3.59	3.89	0.53	1.39	1.85	87.4	90.5	30.2
LSD (0.05)	0.08	0.15	0.15	0.12	0.21	0.18	11.6	14.9	10.4
Significance	***	***	NS	NS	***	**	***	***	NS
Contrast									
Side vs. mid-row	***	NS	NS	NS	0.06	NS	*	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS	***	NS	NS	NS
Urea vs. AA	***	0.07	0.06	NS	*	NS	NS	NS	NS
Fall vs. spring	*[1]	*	NS	NS	0.08	NS	NS	NS	NS
Orthogonal contrasts for N rate									
Linear	***	***	NS	NS	***	**	***	***	**
Quadratic	***	***	NS	NS	NS	NS	*	***	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 24. Grain and straw-N concentration and total N uptake in canola at Star City.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.43	4.40	3.51	0.47	1.22	0.52	111.0	84.0	72.1
2) Side-banded urea with medium rate	3.53	4.99	4.12	0.46	1.68	0.91	116.8	126.4	130.7
3) Side-banded urea with high rate	3.81	5.18	4.33	0.47	2.04	1.07	120.1	147.7	125.9
4) Mid-row banded urea with low rate	3.20	4.40	3.43	0.51	1.27	0.54	98.5	80.6	63.1
5) Mid-row banded urea with medium rate	3.49	4.97	3.96	0.44	1.57	0.82	101.9	102.5	112.1
6) Mid-row banded urea with high rate	3.56	4.88	4.31	0.44	1.90	1.10	123.2	138.5	120.3
7) Fall banded urea with medium rate	3.59	4.84	4.14	0.38	1.81	0.90	116.6	117.0	107.5
8) Broadcasted urea with medium rate	3.28	4.96	4.02	0.46	1.96	0.85	107.5	126.4	98.7
9) Side-banded AA with low rate	2.96	4.55	3.56	0.54	1.06	0.61	94.7	69.2	68.4
10) Side-banded AA with medium rate	3.54	4.78	4.16	0.36	1.48	1.01	118.5	105.7	128.4
11) Side-banded AA with high rate	4.01	5.17	4.31	0.58	2.15	1.18	151.0	146.1	159.2
12) Mid-row banded AA with low rate	3.29	4.44	3.46	0.56	1.38	0.56	107.6	75.2	65.1
13) Mid-row banded AA with medium rate	3.38	4.89	4.01	0.44	1.90	0.89	116.6	120.5	113.7
14) Mid-row banded AA with high rate	3.59	5.08	4.25	0.59	2.21	0.95	129.1	155.0	132.9
15) Fall banded AA with medium rate	3.32	4.89	4.04	0.47	1.60	0.75	98.6	108.9	91.5
16) Very low N	2.98	4.11	3.73	0.51	1.14	0.62	72.7	48.5	36.3
17) Side-banded urea with medium rate + P	3.52	4.93	4.23	0.49	1.87	0.99	126.2	120.4	118.3
Mean	3.44	4.79	3.97	0.48	1.66	0.84	112.4	110.2	102.6
LSD (0.05)	0.24	0.24	0.17	0.17	0.34	0.13	18.4	27.2	19.1
Significance	***	***	***	NS	***	***	***	***	***
Contrast									
Side vs. mid-row	*	NS	**	NS	NS	**	NS	NS	NS
Broadcast vs. banding	*	NS	NS	NS	*	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	NS	0.08	0.07	NS	NS
Fall vs. spring	NS	NS	NS	NS	NS	0.05[1]	NS[1]	NS	NS
Orthogonal contrasts for N rate									
Linear	***	***	***	NS	**	***	***	***	***
Quadratic	NS	NS	***	NS	0.06	***	NS	NS	NS
Cubic	NS	NS	***	NS	NS	***	NS	NS	NS

Table 25. Grain and straw-N concentration and total N uptake in flax at Star City.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.55	4.42	3.71	0.66	0.87	1.34	91.9	101.9	51.9
2) Side-banded urea with medium rate	3.98	4.55	3.93	0.74	0.98	1.40	105.7	101.3	61.3
3) Side-banded urea with high rate	4.20	4.48	3.94	0.76	0.86	1.47	112.8	84.6	63.2
4) Mid-row banded urea with low rate	3.53	4.29	3.55	0.61	0.82	1.24	89.5	92.1	57.5
5) Mid-row banded urea with medium	3.85	4.54	3.77	0.68	1.00	1.39	93.3	106.2	68.8
6) Mid-row banded urea with high rate	3.91	4.53	3.92	0.70	1.04	1.43	98.6	97.8	61.6
7) Fall banded urea with medium rate	3.96	4.41	3.83	0.66	1.02	1.36	97.7	87.3	42.8
8) Broadcasted urea with medium rate	3.77	4.55	3.81	0.56	0.91	1.33	92.2	98.5	62.4
9) Side-banded AA with low rate	3.47	4.30	3.61	0.65	0.77	1.20	91.4	100.5	52.4
10) Side-banded AA with medium rate	3.80	4.55	3.90	0.61	1.02	1.33	98.0	103.3	60.3
11) Side-banded AA with high rate	4.19	4.54	3.84	0.76	0.91	1.63	111.3	95.7	57.0
12) Mid-row banded AA with low rate	3.43	4.30	3.43	0.63	0.79	1.25	85.1	100.5	53.0
13) Mid-row banded AA with medium rate	4.04	4.54	3.77	0.73	0.87	1.39	100.6	96.4	64.4
14) Mid-row banded AA with high rate	4.16	4.50	3.91	0.86	0.92	1.48	112.4	101.6	72.7
15) Fall banded AA with medium rate	3.75	4.50	3.90	0.66	0.94	1.29	97.6	96.6	40.6
16) Very low N	3.24	4.14	3.31	0.59	0.68	1.03	73.0	78.3	39.3
17) Side-banded urea with medium rate +	3.91	4.61	3.85	0.68	1.04	1.51	101.8	94.2	63.9
Mean	3.81	4.46	3.76	0.68	0.91	1.36	97.2	96.3	57.2
LSD (0.05)	0.15	0.21	0.16	0.16	0.16	0.28	10.9	13.9	9.1
Significance	***	**	***	NS	***	*	***	*	***
Contrast									
Side vs. mid-row	NS	NS	**	NS	NS	NS	*	NS	**
Broadcast vs. banding	*	NS	NS	*	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fall vs. spring	NS	NS	NS	NS	NS	NS	NS	**	***
Orthogonal contrasts for N rate									
Linear	***	***	***	**	***	***	***	**	***
Quadratic	NS	*	*	NS	0.05	NS	NS	***	**
Cubic	**	NS	NS	NS	NS	NS	NS	NS	NS

Table 26. Grain and straw-N concentration and total N uptake in wheat at Scott.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	2.35	2.80	3.59	0.58	1.24	1.55	58.3	58.9	15.3
2) Side-banded urea with medium rate	2.54	3.32	3.48	0.72	1.27	1.39	83.3	70.5	13.8
3) Side-banded urea with high rate	2.67	3.55	3.69	0.97	1.54	1.54	115.0	63.2	14.4
4) Mid-row banded urea with low rate	2.32	2.72	3.43	0.79	1.11	1.42	54.5	58.1	13.6
5) Mid-row banded urea with medium	2.48	3.14	3.58	0.86	1.34	1.40	84.2	61.8	13.5
6) Mid-row banded urea with high rate	2.59	3.32	3.52	0.83	1.06	1.59	92.9	68.3	13.7
7) Fall banded urea with medium rate	2.35	3.32	3.77	0.81	1.06	1.43	94.4	59.7	14.7
8) Broadcasted urea with medium rate	2.54	2.91	3.63	0.79	1.35	1.46	72.4	70.6	11.0
9) Side-banded AA with low rate	2.39	2.57	3.36	0.83	1.12	1.34	58.0	48.9	14.1
10) Side-banded AA with medium rate	2.40	3.04	3.63	0.78	1.39	1.44	68.3	63.7	13.4
11) Side-banded AA with high rate	2.66	3.41	3.72	0.98	1.25	1.42	118.4	58.0	12.1
12) Mid-row banded AA with low rate	2.42	2.51	3.56	0.73	0.93	1.37	43.1	55.7	13.1
13) Mid-row banded AA with medium rate	2.40	3.06	3.71	0.83	1.21	1.40	65.2	65.8	11.6
14) Mid-row banded AA with high rate	2.48	3.20	3.76	1.06	1.29	1.48	79.0	82.4	12.4
15) Fall banded AA with medium rate	2.41	3.02	3.77	0.93	1.37	1.34	74.1	69.9	13.6
16) Very low N	2.49	2.22	3.30	0.88	1.11	1.29	36.8	42.4	15.4
17) Side-banded urea with medium rate +	2.43	3.29	3.73	0.80	1.45	1.40	84.9	72.5	13.7
Mean	2.47	3.02	3.60	0.83	1.24	1.43	75.4	63.0	13.5
LSD (0.05)	0.09	0.19	0.31	0.26	0.43	0.32	12.6	15.6	3.1
Significance	***	***	NS	NS	NS	NS	***	**	NS
Contrast									
Side vs. mid-row	**	**	NS	NS	NS	NS	***	NS	NS
Broadcast vs. banding	NS	***	NS	NS	NS	NS	*	NS	NS
Urea vs. AA	0.09	***	NS	NS	NS	NS	**	NS	0.07
Fall vs. spring	0.07[1]	NS	NS	NS	NS	NS	*	NS	NS
Orthogonal contrasts for N rate									
Linear	**	***	**	**	NS	NS	***	***	0.06
Quadratic	***	NS	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 27. Grain and straw-N concentration and total N uptake in canola at Scott.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1})		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.06	3.86	4.50	0.23	1.55	1.61	50.1	70.3	43.1
2) Side-banded urea with medium rate	2.88	4.25	4.56	0.30	1.77	1.84	52.5	80.2	51.4
3) Side-banded urea with high rate	3.06	4.54	4.88	0.29	2.05	1.87	68.0	102.8	58.5
4) Mid-row banded urea with low rate	3.03	3.67	4.41	0.29	1.51	1.41	48.0	64.7	44.8
5) Mid-row banded urea with medium	2.92	4.12	4.67	0.30	1.72	1.86	53.6	80.8	46.6
6) Mid-row banded urea with high rate	3.10	4.57	4.85	0.31	2.03	1.66	61.6	89.3	52.2
7) Fall banded urea with medium rate	2.94	4.28	4.66	0.26	1.47	1.70	52.4	81.6	60.3
8) Broadcasted urea with medium rate	2.90	4.29	4.74	0.28	1.78	1.93	46.7	80.8	63.4
9) Side-banded AA with low rate	2.94	3.69	4.77	0.25	1.38	1.72	39.5	54.8	48.0
10) Side-banded AA with medium rate	2.78	3.93	4.51	0.37	1.61	2.08	48.9	78.2	53.1
11) Side-banded AA with high rate	3.19	4.59	4.62	0.28	2.02	1.91	63.3	90.0	56.9
12) Mid-row banded AA with low rate	2.84	3.56	4.62	0.46	1.49	1.54	37.9	57.7	50.2
13) Mid-row banded AA with medium rate	2.96	4.28	4.62	0.44	1.60	1.95	38.4	72.2	45.4
14) Mid-row banded AA with high rate	2.97	4.47	4.68	0.31	1.92	1.85	49.7	95.4	51.6
15) Fall banded AA with medium rate	2.91	4.06	4.82	0.30	1.51	1.83	46.1	76.2	53.8
16) Very low N	2.98	3.56	4.31	0.32	1.41	1.25	29.5	49.1	37.4
17) Side-banded urea with medium rate +	2.91	4.17	4.73	0.28	1.88	1.86	53.9	88.4	61.3
Mean	2.96	4.11	4.64	0.31	1.69	1.76	49.4	77.2	51.6
LSD (0.05)	0.34	0.48	0.48	0.19	0.31	0.37	15.5	15.6	17.0
Significance	NS	***	NS	NS	***	**	***	***	NS
Contrast									
Side vs. mid-row	NS	NS	NS	NS	NS	NS	**	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	NS	0.09	NS	*	NS
Fall vs. spring	NS	NS	NS	NS	NS	NS	NS	NS	NS
Orthogonal contrasts for N rate									
Linear	NS	***	*	NS	***	***	***	***	**
Quadratic	NS	NS	NS	NS	0.05	*	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 28. Grain and straw-N concentration and total N uptake in flax at Scott.

	Grain N (%)			Straw-N (%)			N uptake (kg ha^{-1}		
Treatment	2000	2001	2002	2000	2001	2002	2000	2001	2002
1) Side-banded urea with low rate	3.26	3.95	4.69	0.33	1.65	2.31	72.5	80.7	26.5
2) Side-banded urea with medium rate	3.70	4.44	4.66	0.35	1.83	2.24	93.1	88.1	28.9
3) Side-banded urea with high rate	3.87	4.51	4.73	0.40	1.73	2.31	104.4	86.1	25.6
4) Mid-row banded urea with low rate	3.41	3.71	4.79	0.34	1.64	2.23	67.1	88.3	28.6
5) Mid-row banded urea with medium	3.68	4.38	4.54	0.42	1.97	2.20	95.1	87.8	25.1
6) Mid-row banded urea with high rate	4.06	4.25	4.60	0.37	1.82	2.26	106.3	105.2	25.1
7) Fall banded urea with medium rate	3.75	4.18	4.53	0.44	1.42	2.28	92.6	90.4	21.7
8) Broadcasted urea with medium rate	3.43	4.23	4.77	0.36	1.63	2.22	75.8	89.7	26.7
9) Side-banded AA with low rate	3.16	3.83	4.63	0.48	1.66	2.27	66.9	75.7	24.2
10) Side-banded AA with medium rate	3.53	4.06	4.52	0.36	1.67	2.33	87.0	94.7	19.7
11) Side-banded AA with high rate	3.91	4.37	4.67	0.46	2.02	2.57	106.7	101.1	26.7
12) Mid-row banded AA with low rate	3.09	3.85	4.55	0.40	1.79	2.21	57.9	84.2	24.6
13) Mid-row banded AA with medium rate	3.53	4.18	4.75	0.41	1.82	2.25	77.4	93.5	25.1
14) Mid-row banded AA with high rate	3.54	4.24	4.78	0.40	1.88	2.32	85.4	101.5	32.3
15) Fall banded AA with medium rate	3.33	4.28	4.60	0.40	1.72	2.26	71.7	88.5	25.4
16) Very low N	3.32	3.62	4.48	0.36	1.38	2.11	48.5	60.8	28.4
17) Side-banded urea with medium rate +	3.60	4.47	4.65	0.41	1.91	2.48	91.9	82.3	25.8
Mean	3.54	4.15	4.64	0.39	1.74	2.29	82.4	88.1	25.9
LSD (0.05)	0.33	0.33	0.SS	0.13	0.37	0.25	10.8	17.5	10.7
Significance	***	***	NS	NS	NS	NS	***	**	NS
Contrast									
Side vs. mid-row	NS	NS	NS	NS	NS	NS	**	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS	NS	***	NS	NS
Urea vs. AA	**	0.06	NS	0.07	NS	NS	***	NS	NS
Fall vs. spring	NS	NS	NS	NS	NS	NS	NS	NS	NS
Orthogonal contrasts for N rate									
Linear	***	***	NS	NS	***	*	***	***	NS
Quadratic	0.06	NS	NS	NS	NS	NS	NS	0.08	NS
Cubic	0.05	*	NS	NS	NS	NS	NS	NS	NS

Table 29. Soil available N (kg ha^{-1}) at 0-30 cm at Swift Current in the rotation of Canola-Wheat-Flax.

Treatment	Fall, Canola	Spring, Wheat	Fall, Wheat	Spring, Flax	Fall, Flax
1) Side-banded urea with low rate	16.9	20.9	24.6	37.9	17.1
2) Side-banded urea with medium rate	16.3	27.5	20.7	40.1	18.6
3) Side-banded urea with high rate	18.3	28.4	96.6	50.7	22.6
4) Mid-row banded urea with low rate	14.4	38.8	22.9	66.4	20.5
5) Mid-row banded urea with medium	15.7	49.3	62.1	34.3	18.3
6) Mid-row banded urea with high rate	16.3	34.0	50.7	68.8	25.1
7) Fall banded urea with medium rate	16.7	18.3	47.2	35.8	19.2
8) Broadcasted urea with medium rate	16.8	28.5	39.8	40.7	24.6
9) Side-banded AA with low rate	17.3	25.4	40.3	48.8	19.1
10) Side-banded AA with medium rate	14.4	26.1	39.7	41.0	20.1
11) Side-banded AA with high rate	19.1	27.0	104.5	49.3	29.9
12) Mid-row banded AA with low rate	20.3	27.0	25.1	56.7	17.4
13) Mid-row banded AA with medium rate	21.7	29.6	48.1	104.4	33.4
14) Mid-row banded AA with high rate	18.1	17.6	23.4	40.8	26.7
15) Fall banded AA with medium rate	16.2	32.8	47.3	52.6	20.8
16) Very low N	15.3	26.9	13.9	56.4	18.3
17) Side-banded urea with medium rate +	16.5	20.5	31.9	17.6	20.7
Mean	17.1	28.1	43.5	49.5	21.9
LSD (0.05)	7.3	20.3	54.7	53.9	12.5
Significance	NS	NS	NS	NS	NS
Contrast					
Side vs. mid-row	NS	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	NS
Fall vs. spring	NS	NS	NS	NS	NS
Orthogonal contrasts for N rate					
Linear	NS	NS	*	NS	0.09
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 30. Soil available N (kg ha^{-1}) at 0-30 cm at Swift Current in the rotation of Wheat-Flax-Canola.

Treatment	Fall, Wheat	Spring, Flax	Fall, Flax	Spring, Canola	Fall, Canola
1) Side-banded urea with low rate	15.9	17.8	21.3	37.7	24.4
2) Side-banded urea with medium rate	16.2	21.2	28.3	51.2	25.3
3) Side-banded urea with high rate	23.2	19.2	72.0	37.8	42.7
4) Mid-row banded urea with low rate	20.9	23.6	25.4	43.8	25.6
5) Mid-row banded urea with medium	14.8	21.6	32.8	32.8	21.8
6) Mid-row banded urea with high rate	21.7	27.8	94.5	52.7	34.0
7) Fall banded urea with medium rate	20.0	46.2	44.9	32.7	34.6
8) Broadcasted urea with medium rate	19.0	20.8	23.5	31.9	32.0
9) Side-banded AA with low rate	13.2	21.0	22.2	32.0	22.4
10) Side-banded AA with medium rate	14.6	29.0	64.5	29.6	32.8
11) Side-banded AA with high rate	18.4	18.2	37.6	31.5	40.8
12) Mid-row banded AA with low rate	11.9	23.6	7.4	31.6	22.8
13) Mid-row banded AA with medium rate	22.9	20.5	38.6	33.7	25.8
14) Mid-row banded AA with high rate	21.3	20.7	15.2	34.0	26.4
15) Fall banded AA with medium rate	22.9	18.8	47.7	30.9	35.0
16) Very low N	14.1	46.1	10.9	38.3	23.9
17) Side-banded urea with medium rate +	21.6	23.8	40.9	51.1	33.3
Mean	18.4	24.7	36.9	37.3	29.6
LSD (0.05)	9.7	25.3	44.2	27.9	12.9
Significance	NS	NS	*	NS	*
Contrast					
Side vs. mid-row	NS	NS	NS	NS	*
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	0.06	NS
Fall vs. spring	NS	*[1]	NS	NS	*
Orthogonal contrasts for N rate					
Linear	0.06	NS	*	NS	*
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 31. Soil available N (kg ha^{-1}) at 0-30 cm at Swift Current in the rotation of Flax-Canola-Wheat.

Treatment	Fall, Flax	Spring, Canola	Fall, Canola	Spring, Wheat	Fall, Wheat
1) Side-banded urea with low rate	20.1	25.5	12.1	67.0	32.3
2) Side-banded urea with medium rate	17.1	29.8	12.2	87.8	26.3
3) Side-banded urea with high rate	41.9	68.9	52.0	54.6	40.8
4) Mid-row banded urea with low rate	18.5	21.5	24.3	34.2	34.5
5) Mid-row banded urea with medium	14.7	29.6	15.7	80.2	32.5
6) Mid-row banded urea with high rate	46.7	24.0	27.9	42.1	31.9
7) Fall banded urea with medium rate	24.6	27.4	16.1	72.7	38.5
8) Broadcasted urea with medium rate	12.8	23.1	17.2	59.6	31.4
9) Side-banded AA with low rate	10.9	24.9	17.0	61.2	28.4
10) Side-banded AA with medium rate	12.4	18.2	26.5	52.6	29.4
11) Side-banded AA with high rate	16.7	21.9	20.6	58.9	34.6
12) Mid-row banded AA with low rate	15.9	40.7	11.4	85.0	28.8
13) Mid-row banded AA with medium rate	13.0	23.7	16.6	67.4	31.8
14) Mid-row banded AA with high rate	20.4	23.6	13.8	43.8	29.6
15) Fall banded AA with medium rate	20.6	39.1	17.7	73.3	30.4
16) Very low N	10.1	40.0	9.8	82.2	28.6
17) Side-banded urea with medium rate +	22.8	34.2	18.1	51.5	34.4
Mean	19.9	30.4	19.4	63.2	32.0
LSD (0.05)	20.6	36.4	20.7	56.0	8.4
Significance	*	NS	0.05	NS	NS
Contrast					
Side vs. mid-row	NS	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	*	NS	NS	NS	NS
Fall vs. spring	NS	NS	NS	NS	0.08[1]
Orthogonal contrasts for N rate					
Linear	*	NS	0.06	NS	NS
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 32. Soil available N (kg ha-1) at 0-30 cm at Indian Head in the rotation of Canola-Wheat-Flax.

Treatment	Fall, Canola	Spring, Wheat	Fall, Wheat	Spring, Flax	Fall, 2002 Flax
1) Side-banded urea with low rate	35.8	45.4	85.9	97.8	47.6
2) Side-banded urea with medium rate	35.2	45.6	99.9	109.4	53.2
3) Side-banded urea with high rate	50.6	51.8	122.2	123.1	57.8
4) Mid-row banded urea with low rate	38.6	36.7	55.7	74.4	34.7
5) Mid-row banded urea with medium	38.9	50.3	60.7	77.3	58.8
6) Mid-row banded urea with high rate	43.2	56.2	341.5	124.7	40.5
7) Fall banded urea with medium rate	41.5	76.5	104.6	117.5	47.5
8) Broadcasted urea with medium rate	39.2	44.8	85.8	87.4	53.7
9) Side-banded AA with low rate	35.4	49.1	55.8	74.7	50.3
10) Side-banded AA with medium rate	33.0	40.7	84.6	95.4	55.2
11) Side-banded AA with high rate	44.9	51.1	101.2	158.6	87.7
12) Mid-row banded AA with low rate	37.1	41.1	156.4	49.0	47.1
13) Mid-row banded AA with medium rate	34.7	35.3	149.2	101.3	62.7
14) Mid-row banded AA with high rate	33.6	44.3	173.4	152.2	60.6
15) Fall banded AA with medium rate	31.6	91.6	83.2	97.8	42.0
16) Very low N	34.6	39.8	50.2	34.6	51.0
17) Side-banded urea with medium rate +	36.5	47.1	91.9	139.8	68.5
Mean	37.9	49.8	111.9	100.9	54.0
LSD (0.05)	8.2	30.0	132.0	80.3	24.2
Significance	**	0.05	*	NS	*
Contrast					
Side vs. mid-row	NS	NS	*	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	*	NS	NS	NS	*
Fall vs. spring	NS	***	NS	NS	NS
Orthogonal contrasts for N rate					
Linear	*	0.06	*	***	0.09
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 33. Soil available N (kg ha^{-1}) at 0-30 cm at Indian Head in the rotation of Wheat-Flax-Canola.

Treatment	Fall, Wheat	Spring, Flax	Fall, Flax	Spring, Can	Fall, 2002 Canola
1) Side-banded urea with low rate	39.6	43.2	50.7	49.8	43.0
2) Side-banded urea with medium rate	44.1	36.7	147.6	77.3	45.9
3) Side-banded urea with high rate	46.7	49.6	126.5	103.7	61.8
4) Mid-row banded urea with low rate	41.0	48.0	68.7	40.5	38.8
5) Mid-row banded urea with medium	38.5	43.4	46.9	75.7	43.4
6) Mid-row banded urea with high rate	43.9	48.8	127.5	143.5	48.1
7) Fall banded urea with medium rate	45.8	70.6	73.6	163.5	57.0
8) Broadcasted urea with medium rate	35.6	42.3	26.7	47.6	52.2
9) Side-banded AA with low rate	40.7	43.9	36.2	34.5	29.9
10) Side-banded AA with medium rate	34.8	42.4	65.5	53.9	43.3
11) Side-banded AA with high rate	50.4	54.3	105.5	68.0	68.8
12) Mid-row banded AA with low rate	40.3	42.8	39.5	55.7	46.5
13) Mid-row banded AA with medium rate	36.8	40.1	45.4	117.6	50.8
14) Mid-row banded AA with high rate	43.9	41.1	56.0	52.4	56.7
15) Fall banded AA with medium rate	43.4	134.8	73.3	60.5	46.8
16) Very low N	36.6	47.3	28.3	28.9	42.0
17) Side-banded urea with medium rate +	34.8	44.0	77.0	80.7	48.3
Mean	41.0	51.4	70.3	73.8	48.4
LSD (0.05)	12.5	25.3	72.2	75.1	19.1
Significance	NS	***	*	*	0.05
Contrast					
Side vs. mid-row	NS	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	*	NS	NS
Urea vs. AA	NS	NS	*	NS	NS
Fall vs. spring	NS	***	NS	NS[1]	NS
Orthogonal contrasts for N rate					
Linear	*	NS	*	*	*
Quadratic	NS	NS	NS	NS	0.08
Cubic	NS	NS	NS	NS	NS

Table 34. Soil available N (kg ha-1) at 0-30 cm at Indian Head in the rotation of Flax-Canola-Wheat.

Treatment	Fall, Flax	Spring, Canola	Fall, Canola	Spring, Wheat	Fall, 2002 Wheat
1) Side-banded urea with low rate	25.5	37.9	28.8	56.3	33.5
2) Side-banded urea with medium rate	35.6	48.0	44.0	51.6	43.1
3) Side-banded urea with high rate	48.1	55.0	68.7	66.2	58.2
4) Mid-row banded urea with low rate	31.3	33.8	30.8	42.4	40.0
5) Mid-row banded urea with medium	32.6	38.0	29.8	53.8	46.9
6) Mid-row banded urea with high rate	46.1	54.7	138.0	68.7	47.8
7) Fall banded urea with medium rate	36.9	69.0	34.4	88.6	45.4
8) Broadcasted urea with medium rate	38.7	45.1	39.5	46.8	43.7
9) Side-banded AA with low rate	34.1	40.5	24.0	39.9	32.3
10) Side-banded AA with medium rate	43.2	37.7	39.6	66.3	44.3
11) Side-banded AA with high rate	52.7	72.9	119.8	94.9	66.7
12) Mid-row banded AA with low rate	29.5	36.2	29.4	32.7	35.1
13) Mid-row banded AA with medium rate	34.3	40.3	26.0	35.4	37.4
14) Mid-row banded AA with high rate	38.5	45.6	40.4	60.9	43.8
15) Fall banded AA with medium rate	34.1	69.1	36.7	57.3	44.0
16) Very low N	27.7	38.4	24.7	33.3	29.1
17) Side-banded urea with medium rate +	34.3	39.3	47.1	37.8	40.7
Mean	36.6	47.1	47.2	54.9	43.0
LSD (0.05)	16.4	23.1	89.8	38.6	19.6
Significance	NS	**	NS	0.06	0.07
Contrast					
Side vs. mid-row	NS	*	NS	0.08	NS
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	NS
Fall vs. spring	NS	***	NS	NS	NS
Orthogonal contrasts for N rate					
Linear	**	**	0.08	**	**
Quadratic	NS	*	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 35. Soil available N (kg ha^{-1}) at 0-30 cm at Star City in the rotation of Canola-Wheat-Flax.

Treatment	Fall, Canola	Spring, Wheat	Fall, Wheat	Spring, Flax	Fall, Flax
1) Side-banded urea with low rate	22.6	36.6	32.0	52.8	37.7
2) Side-banded urea with medium rate	25.6	36.0	41.8	57.2	51.3
3) Side-banded urea with high rate	33.3	33.1	86.0	48.6	100.5
4) Mid-row banded urea with low rate	22.7	40.4	22.2	60.5	23.9
5) Mid-row banded urea with medium	29.0	37.0	29.0	44.9	49.1
6) Mid-row banded urea with high rate	29.2	34.2	85.9	27.7	59.5
7) Fall banded urea with medium rate	23.5	36.9	54.8	40.6	80.2
8) Broadcasted urea with medium rate	20.5	32.7	34.0	39.0	65.0
9) Side-banded AA with low rate	21.4	38.9	21.9	63.6	31.5
10) Side-banded AA with medium rate	21.4	34.9	30.1	39.2	75.4
11) Side-banded AA with high rate	27.7	34.7	83.3	71.8	116.0
12) Mid-row banded AA with low rate	19.8	31.6	36.9	31.9	31.9
13) Mid-row banded AA with medium rate	25.2	33.7	22.1	66.7	44.9
14) Mid-row banded AA with high rate	24.7	39.2	22.3	33.0	55.0
15) Fall banded AA with medium rate	25.1	37.0	35.3	29.0	53.2
16) Very low N	14.3	39.7	21.3	37.9	29.1
17) Side-banded urea with medium rate +	21.8	32.7	51.7	45.2	61.3
Mean	24.0	35.8	41.8	46.4	56.8
LSD (0.05)	7.6	9.3	32.5	43.6	35.4
Significance	**	NS	***	NS	***
Contrast					
Side vs. mid-row	NS	NS	0.07	NS	**
Broadcast vs. banding	*	NS	NS	NS	NS
Urea vs. AA	*	NS	0.06	NS	NS
Fall vs. spring	NS	NS	NS	NS	NS
Orthogonal contrasts for N rate					
Linear	***	NS	**	NS	***
Quadratic	NS	NS	0.08	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 36. Soil available N (kg ha^{-1}) at 0-30 cm at Star City in the rotation of Wheat-Flax-Canola.

Treatment	Fall, Wheat	Spring, Flax	Fall, Flax	Spring, Canola	Fall, Canola
1) Side-banded urea with low rate	21.4	28.8	28.4	42.2	17.8
2) Side-banded urea with medium rate	23.7	63.7	47.6	59.8	34.2
3) Side-banded urea with high rate	49.4	31.2	78.5	47.0	67.3
4) Mid-row banded urea with low rate	30.3	42.9	29.4	45.7	19.0
5) Mid-row banded urea with medium	27.6	23.8	22.8	32.2	27.4
6) Mid-row banded urea with high rate	31.2	19.7	90.8	34.6	52.2
7) Fall banded urea with medium rate	37.1	26.1	42.3	58.0	46.4
8) Broadcasted urea with medium rate	23.7	29.5	47.2	43.8	32.8
9) Side-banded AA with low rate	30.9	25.5	28.3	41.7	27.4
10) Side-banded AA with medium rate	25.4	21.9	40.3	33.4	34.3
11) Side-banded AA with high rate	36.8	23.2	125.5	29.0	79.3
12) Mid-row banded AA with low rate	30.4	22.7	20.4	27.9	22.0
13) Mid-row banded AA with medium rate	30.0	25.6	34.2	40.9	29.0
14) Mid-row banded AA with high rate	33.4	23.1	30.9	32.6	53.2
15) Fall banded AA with medium rate	31.9	26.0	32.7	49.1	38.1
16) Very low N	15.2	50.0	21.7	64.4	19.6
17) Side-banded urea with medium rate +	25.6	23.3	60.4	34.9	48.2
Mean	29.6	29.8	46.0	42.2	38.1
LSD (0.05)	14.6	32.8	34.0	32.3	20.2
Significance	*	NS	***	NS	***
Contrast					
Side vs. mid-row	NS	NS	*	NS	*
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	NS
Fall vs. spring	0.09	NS	NS	NS	0.08
Orthogonal contrasts for N rate					
Linear	**	NS	***	*	***
Quadratic	NS	NS	0.06	NS	**
Cubic	NS	NS	NS	NS	NS

Table 37. Soil available N (kg ha^{-1}) at 0-30 cm at Star City in the rotation of Flax-Canola-Wheat.

Treatment	Fall, Flax	Spring, Canola	Fall, Canola	Spring, Wheat	Fall, Wheat
1) Side-banded urea with low rate	17.6	35.3	19.5	29.7	46.1
2) Side-banded urea with medium rate	17.5	27.9	31.2	36.4	65.0
3) Side-banded urea with high rate	31.5	25.9	49.6	32.4	115.9
4) Mid-row banded urea with low rate	15.4	25.8	24.9	62.3	42.4
5) Mid-row banded urea with medium	17.1	30.7	34.7	51.1	80.1
6) Mid-row banded urea with high rate	22.8	50.0	33.7	66.7	77.5
7) Fall banded urea with medium rate	23.8	30.0	29.2	60.0	76.6
8) Broadcasted urea with medium rate	19.9	24.4	29.7	60.6	79.6
9) Side-banded AA with low rate	13.8	44.7	22.1	75.7	43.0
10) Side-banded AA with medium rate	22.1	25.9	29.2	58.2	50.7
11) Side-banded AA with high rate	29.7	38.6	84.3	106.7	102.3
12) Mid-row banded AA with low rate	20.1	30.5	25.4	37.3	40.5
13) Mid-row banded AA with medium rate	18.2	33.4	26.4	81.7	68.7
14) Mid-row banded AA with high rate	35.2	26.9	51.1	49.9	179.1
15) Fall banded AA with medium rate	15.4	27.0	34.5	83.1	54.8
16) Very low N	9.0	24.1	19.8	58.0	33.7
17) Side-banded urea with medium rate +	19.3	30.1	29.4	65.1	53.2
Mean	20.5	31.2	33.8	59.7	71.1
LSD (0.05)	10.8	22.1	18.2	56.3	39.7
Significance	**	NS	***	NS	***
Contrast					
Side vs. mid-row	NS	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	0.09	0.07[1]	NS
Fall vs. spring	NS	NS	NS	NS	NS
Orthogonal contrasts for N rate					
Linear	***	NS	***	NS	***
Quadratic	NS	NS	0.06	NS	0.07
Cubic	NS	NS	NS	NS	NS

Table 38. Soil available N (kg ha^{-1}) at 0-30 cm at Scott in the rotation of Canola-Wheat-Flax.

Treatment	Fall, Canola	Spring, Wheat	Fall, Wheat	Spring, Flax	Fall, Flax
1) Side-banded urea with low rate	15.2	22.8	24.6	22.4	75.6
2) Side-banded urea with medium rate	16.2	22.5	36.0	27.0	116.5
3) Side-banded urea with high rate	15.9	25.2	31.9	58.5	103.1
4) Mid-row banded urea with low rate	15.4	25.3	24.8	19.5	53.6
5) Mid-row banded urea with medium	15.1	23.2	23.7	30.7	78.4
6) Mid-row banded urea with high rate	21.3	27.7	51.9	69.4	104.6
7) Fall banded urea with medium rate	.	65.3	40.0	67.2	112.3
8) Broadcasted urea with medium rate	.	24.0	33.9	43.2	67.4
9) Side-banded AA with low rate	18.0	25.7	32.5	21.0	55.2
10) Side-banded AA with medium rate	17.4	19.9	26.1	44.0	81.5
11) Side-banded AA with high rate	17.5	22.5	33.2	35.7	96.8
12) Mid-row banded AA with low rate	11.8	23.3	24.1	19.4	67.6
13) Mid-row banded AA with medium rate	40.6	22.8	42.6	22.8	86.9
14) Mid-row banded AA with high rate	16.2	24.3	26.2	26.3	67.2
15) Fall banded AA with medium rate	.	92.9	24.6	153.6	82.3
16) Very low N	13.6	24.7	23.3	18.4	72.4
17) Side-banded urea with medium rate +	.	22.7	33.0	28.0	93.9
Mean	13.8	30.3	31.3	41.6	83.2
LSD (0.05)	21.8	22.2	24.1	49.0	61.9
Significance	NS	***	NS	***	NS
Contrast					
Side vs. mid-row	NS	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	NS
Fall vs. spring	NS	***	NS	***	NS
Orthogonal contrasts for N rate					
Linear	NS	NS	NS	***[1]	NS
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 39. Soil available N (kg ha^{-1}) at 0-30 cm at Scott in the rotation of Wheat-Flax-Canola.

Treatment	Fall, Wheat	Spring, Flax	Fall, Flax	Spring, Canola	Fall, Canola
1) Side-banded urea with low rate	16.0	27.5	17.2	17.3	48.0
2) Side-banded urea with medium rate	19.3	29.0	41.6	29.0	67.9
3) Side-banded urea with high rate	16.5	29.8	34.6	60.8	75.9
4) Mid-row banded urea with low rate	17.3	28.7	14.7	11.2	30.1
5) Mid-row banded urea with medium	17.8	27.5	25.7	28.5	70.4
6) Mid-row banded urea with high rate	13.5	23.5	37.4	38.4	78.9
7) Fall banded urea with medium rate	.	106.8	17.7	95.3	44.9
8) Broadcasted urea with medium rate	.	31.9	29.3	29.7	69.7
9) Side-banded AA with low rate	16.5	23.0	20.1	14.3	32.5
10) Side-banded AA with medium rate	16.6	26.5	18.3	33.9	42.0
11) Side-banded AA with high rate	13.1	29.6	44.6	36.7	54.2
12) Mid-row banded AA with low rate	18.7	30.8	19.6	24.4	43.1
13) Mid-row banded AA with medium rate	13.8	22.9	14.7	28.5	41.9
14) Mid-row banded AA with high rate	16.8	26.3	30.4	33.3	46.0
15) Fall banded AA with medium rate	.	69.7	34.4	67.0	58.5
16) Very low N	13.0	30.2	13.1	14.6	32.4
17) Side-banded urea with medium rate +	.	25.0	27.7	25.7	58.7
Mean	12.3	34.6	25.9	34.6	52.6
LSD (0.05)	7.2	27.8	20.6	38.6	37.9
Significance	NS	***	*	**	NS
Contrast					
Side vs. mid-row	NS	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	*
Fall vs. spring	NS	***	NS	**	NS
Orthogonal contrasts for N rate					
Linear	NS	NS	**	**	*
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 40. Soil available N (kg ha^{-1}) at 0-30 cm at Scott in the rotation of Flax-Canola-Wheat.

Treatment	Fall, Flax	Spring, Canola	Fall, Canola	Spring, Wheat	Fall, Wheat
1) Side-banded urea with low rate	16.6	19.9	21.6	21.3	90.8
2) Side-banded urea with medium rate	13.2	24.1	19.1	23.8	90.3
3) Side-banded urea with high rate	17.2	18.3	26.1	35.4	89.2
4) Mid-row banded urea with low rate	15.4	16.8	18.6	19.9	83.7
5) Mid-row banded urea with medium	13.4	18.1	22.1	23.8	153.6
6) Mid-row banded urea with high rate	15.6	23.1	25.3	28.6	84.2
7) Fall banded urea with medium rate	.	93.4	22.6	39.4	97.4
8) Broadcasted urea with medium rate	.	17.9	24.3	37.4	91.4
9) Side-banded AA with low rate	13.8	13.5	20.4	20.7	84.9
10) Side-banded AA with medium rate	11.2	18.2	19.4	20.8	70.2
11) Side-banded AA with high rate	12.8	19.3	21.3	22.2	100.2
12) Mid-row banded AA with low rate	16.3	18.5	19.4	22.9	67.9
13) Mid-row banded AA with medium rate	14.1	18.8	21.6	26.0	76.5
14) Mid-row banded AA with high rate	11.9	23.1	27.6	31.6	69.7
15) Fall banded AA with medium rate	.	152.0	19.6	48.0	80.8
16) Very low N	10.1	21.4	21.2	28.2	59.0
17) Side-banded urea with medium rate +	.	15.4	22.0	26.3	103.1
Mean	10.7	31.3	21.9	28.0	87.8
LSD (0.05)	8.5	89.2	9.3	22.8	48.1
Significance	NS	NS	NS	NS	NS
Contrast					
Side vs. mid-row	NS	NS	NS	NS	NS
Broadcast vs. banding	NS	NS	NS	NS	NS
Urea vs. AA	NS	NS	NS	NS	*
Fall vs. spring	NS	**	NS	*	NS
Orthogonal contrasts for N rate					
Linear	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

Table 41. Estimates of seasonal and annual (May 2000-April 2001) N_2O losses measured at Swift Current, and significance levels for selected treatment contrasts.

Treatment	**Frost-free 2000**	**Spring 2001**	**Annual [Z]**
	grams N ha^{-1}		
AA Fall band	149	152	301
AA Side-row band	100	146	246
AA Mid-row band	318	93	411
Urea Fall band	135	205	340
Urea Side-row band	196	105	302
Urea Mid-row band (0.5x rate)	130	116	246
Urea Mid-row band	282	112	393
Urea Mid-row band (1.5x rate)	547	114	661
Urea broadcast	188	214	403
Check (no N applied)	94	137	231
Contrasts	**Significance**		
N applied vs. no N applied	< 0.01	ns [Y]	0.08
Fall banded N vs. Spring banded N	< 0.01	ns	ns
Mid-row vs. Side-row banded N	< 0.01	ns	0.06
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	ns	0.10	ns
Orthogonal Contrasts for N rate			
rate	< 0.01	ns	< 0.01
linear	< 0.01	ns	< 0.01
quadratic	< 0.01	ns	0.03

[Z] annual estimates include the growing season and fall of 2000 plus spring thaw 2001.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 42. Estimates of seasonal and annual (May 2001-April 2002) N_2O losses measured at Swift Current, and significance levels for selected treatment contrasts.

Treatment	**Frost-free 2001**	**Spring 2002**	**Annual** [z]
	grams N ha^{-1}		
AA Fall band	55	8	63
AA Side-row band	156	0	155
AA Mid-row band	157	2	159
Urea Fall band	37	1	39
Urea Side-row band	56	0	55
Urea Mid-row band (0.5x rate)	78	0	78
Urea Mid-row band	163	0	163
Urea Mid-row band (1.5x rate)	273	4	277
Urea broadcast	110	1	111
Check (no N applied)	28	0	27
Contrasts	**Significance**		
N applied vs. no N applied	0.04	ns [Y]	0.03
Fall banded N vs Spring banded N	< 0.01	< 0.01	0.08
Mid-row vs. Side-row banded N	0.10	ns	0.10
NH3 vs. Urea	ns	0.07	ns
Urea broadcast vs. Urea spring band	ns	ns	ns
Orthogonal Contrasts for N rate			
rate	<0.01	ns	<0.01
linear	0.02	ns	0.01
quadratic	ns	ns	ns

[z] annual estimates include the growing season and fall of 2001 plus spring thaw 2002.

[Y] not significant at p > 0.1, values presented are actual probability levels

Table 43. Estimates of seasonal and annual (May 2002-April 2003) N_2O losses measured at Swift Current, and significance levels for selected treatment contrasts.

Treatment	**Frost-free 2002**	**Spring 2003**	**Annual** [z]
	grams N ha^{-1}		
AA Fall band	260	50	310
AA Side-row band	298	34	332
AA Mid-row band	237	17	254
Urea Fall band	569	28	596
Urea Side-row band	180	28	208
Urea Mid-row band (0.5x rate)	209	13	223
Urea Mid-row band	323	15	338
Urea Mid-row band (1.5x rate)	390	19	409
Urea broadcast	247	19	265
Check (no N applied)	122	13	135
Contrasts	**Significance**		
N applied vs. no N applied	ns [Y]	ns	ns
Fall banded N vs. Spring banded N	ns	0.05	ns
Mid-row vs. Side-row banded N	ns	0.10	ns
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	ns	ns	ns
Orthogonal Contrasts for N rate			
rate	ns	ns	ns
linear	ns	ns	ns
quadratic	ns	ns	ns

[z] annual estimates include the growing season and fall of 2002 plus spring thaw 2003.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 44. Estimates of seasonal and annual (May 2000-April 2001) N_2O losses measured at Scott, and significance levels for selected treatment contrasts.

Treatment	Frost-free 2000	Spring 2001	Annual [z]
	grams N ha^{-1}		
AA Fall band	13	181	194
AA Side-row band	6	104	110
AA Mid-row band	100	66	166
Urea Fall band	172	64	236
Urea Side-row band	30	91	121
Urea Mid-row band (0.5x rate)	8	102	109
Urea Mid-row band	37	78	115
Urea Mid-row band (1.5x rate)	95	97	193
Urea broadcast	44	74	118
Check (no N applied)	-25	110	95
Contrasts	**Significance**		
N applied vs. no N applied	ns [Y]	ns	ns
Fall banded N vs. Spring banded N	ns	ns	ns
Mid-row vs. Side-row banded N	ns	ns	ns
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	ns	ns	ns
Orthogonal Contrasts for N rate			
rate	ns	ns	ns
linear	0.03	ns	ns
quadratic	ns	ns	ns

[z] annual estimates include the growing season and fall of 2000 plus spring thaw 2001.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 45. Estimates of seasonal and annual (May 2001-April 2002) N_2O losses measured at Scott, and significance levels for selected treatment contrasts.

Treatment	Frost-free 2001	Spring 2002	Annual [z]
	grams N ha^{-1}		
AA Fall band	110	17	127
AA Side-row band	59	18	76
AA Mid-row band	175	13	188
Urea Fall band	88	9	97
Urea Side-row band	31	15	46
Urea Mid-row band (0.5x rate)	121	4	125
Urea Mid-row band	69	7	76
Urea Mid-row band (1.5x rate)	340	5	345
Urea broadcast	60	3	63
Check (no N applied)	22	1	23
Contrasts	**Significance**		
N applied vs. no N applied	ns [Y]	0.10	ns
Fall banded N vs. Spring banded N	ns	ns	ns
Mid-row vs. Side-row banded N	0.08	ns	ns
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	ns	ns	ns
Orthogonal Contrasts for N rate			
rate	0.03	ns	0.04
linear	ns	ns	ns
quadratic	ns	ns	ns

[z] annual estimates include the growing season and fall of 2001 plus spring thaw 2002.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 46. Estimates of seasonal and annual (May 2002-April 2003) N_2O losses measured at Scott, and significance levels for selected treatment contrasts.

Treatment	**Frost-free 2002**	**Spring 2003**	**Annual** [Z]
	grams N ha^{-1}		
AA Fall band	163	18	181
AA Side-row band	126	16	142
AA Mid-row band	270	22	292
Urea Fall band	118	18	136
Urea Side-row band	97	15	112
Urea Mid-row band (0.5x rate)	101	18	119
Urea Mid-row band	252	18	271
Urea Mid-row band (1.5x rate)	323	22	346
Urea broadcast	326	20	346
Check (no N applied)	72	18	90
Contrasts	**Significance**		
N applied vs. no N applied	0.02	ns	0.02
Fall banded N vs. Spring banded N	ns	ns	ns
Mid-row vs. Side-row banded N	< 0.01	ns	< 0.01
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	< 0.01	ns	< 0.01
Orthogonal Contrasts for N rate			
rate	0.01	ns	0.01
linear	<0.01	ns	<0.01
quadratic	ns	ns	ns

[Z] annual estimates include the growing season and fall of 2002 plus spring thaw 2003.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 47. Estimates of seasonal and annual (May 2000-April 2001) N_2O losses measured at Indian Head, and significance levels for selected treatment contrasts.

Treatment	Frost-free 2000	Spring 2001	Annual[z]
	grams N ha^{-1}		
AA Fall band	36	151	187
AA Side-row band	133	67	200
AA Mid-row band	72	21	93
Urea Fall band	72	156	218
Urea Side-row band	81	69	150
Urea Mid-row band (0.5x rate)	45	46	92
Urea Mid-row band	115	37	152
Urea Mid-row band (1.5x rate)	59	23	82
Urea broadcast	96	33	129
Check (no N applied)	31	22	52
Contrasts	**Significance**		
N applied vs. no N applied	ns[Y]	0.08	ns
Fall banded N vs. Spring banded N	ns	< 0.01	ns
Mid-row vs. Side-row banded N	ns	ns	ns
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	ns	ns	ns
Orthogonal Contrasts for N rate			
rate	ns	ns	0.01
linear	0.1	ns	< 0.01
quadratic	ns	ns	0.10

[z] annual estimates include the growing season and fall of 2000 plus spring thaw 2001.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 48. Estimates of seasonal and annual (May 2001-April 2002) N_2O losses measured at Indian Head, and significance levels for selected treatment contrasts.

Treatment	Frost-free 2001	Spring 2002	Annual [z]
	grams N ha^{-1}		
AA Fall band	28	19	47
AA Side-row band	23	20	43
AA Mid-row band	48	10	59
Urea Fall band	28	35	64
Urea Side-row band	29	18	46
Urea Mid-row band (0.5x rate)	10	4	14
Urea Mid-row band	19	8	27
Urea Mid-row band (1.5x rate)	21	13	34
Urea broadcast	124	16	140
Check (no N applied)	1	3	4
Contrasts	**Significance**		
N applied vs. no N applied	0.08	0.02	0.08
Fall banded N vs. Spring banded N	ns [Y]	0.01	ns
Mid-row vs. Side-row banded N	0.02	0.08	ns
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	0.06	ns	< 0.01
Orthogonal Contrasts for N rate			
rate	ns	0.08	ns
linear	ns	0.03	ns
quadratic	ns	ns	ns

[z] annual estimates include the growing season and fall of 2001 plus spring thaw 2002.

[Y] not significant at p > 0.1, values presented are actual probability levels

Table 49. Estimates of seasonal and annual (May 2002-April 2003) N_2O losses measured at Indian Head, and significance levels for selected treatment contrasts.

Treatment	**Frost-free 2002**	**Spring 2003**	**Annual** [z]
	grams N ha^{-1}		
AA Fall band	54	17	71
AA Side-row band	69	32	101
AA Mid-row band	66	12	78
Urea Fall band	83	27	110
Urea Side-row band	61	30	90
Urea Mid-row band (0.5x rate)	45	17	62
Urea Mid-row band	66	22	89
Urea Mid-row band (1.5x rate)	94	21	114
Urea broadcast	133	21	154
Check (no N applied)	44	13	57
Contrasts	**Significance**		
N applied vs. no N applied	0.06	ns	0.04
Fall banded N vs. Spring banded N	ns [Y]	ns	ns
Mid-row vs. Side-row banded N	0.02	0.05	ns
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	< 0.01	ns	0.01
Orthogonal Contrasts for N rate			
rate	ns	ns	ns
linear	0.04	ns	0.02
quadratic	ns	ns	ns

[z] annual estimates include the growing season and fall of 2002 plus spring thaw 2003.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 50. Estimates of seasonal and annual (May 2000-April 2001) N_2O losses measured at Star City, and significance levels for selected treatment contrasts.

Treatment	Frost-free 2000	Spring 2001	Annual [Z]
	grams N ha^{-1}		
AA Fall band	71	343	414
AA Side-row band	230	242	472
AA Mid-row band	357	403	760
Urea Fall band	89	582	672
Urea Side-row band	66	96	162
Urea Mid-row band (0.5x rate)	55	405	460
Urea Mid-row band	69	432	501
Urea Mid-row band (1.5x rate)	58	366	424
Urea broadcast	87	253	340
Check (no N applied)	39	592	631
Contrasts	**Significance**		
N applied vs. no N applied	ns [Y]	< 0.01	ns
Fall banded N vs. Spring banded N	ns	0.03	ns
Mid-row vs. Side-row banded N	ns	< 0.01	0.01
NH3 vs. Urea	0.02	ns	0.08
Urea broadcast vs. Urea spring band	ns	ns	ns
Orthogonal Contrasts for N rate			
rate	ns	ns	ns
linear	ns	0.05	ns
quadratic	ns	ns	ns

[Z] annual estimates include the growing season and fall of 2000 plus spring thaw 2001.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 51. Estimates of seasonal and annual (May 2001-April 2002) N_2O losses measured at Star City, and significance levels for selected treatment contrasts.

Treatment	**Frost-free 2001**	**Spring 2002**	**Annual** [z]
	grams N ha^{-1}		
AA Fall band	9	10	19
AA Side-row band	6	2	8
AA Mid-row band	25	6	31
Urea Fall band	9	14	23
Urea Side-row band	9	17	25
Urea Mid-row band (0.5x rate)	8	4	12
Urea Mid-row band	15	3	18
Urea Mid-row band (1.5x rate)	14	11	25
Urea broadcast	9	3	11
Check (no N applied)	3	5	7
Contrasts	**Significance**		
N applied vs. no N applied	0.08	ns	0.05
Fall banded N vs. Spring banded N	ns	ns	ns
Mid-row vs. Side-row banded N	< 0.01	ns	0.01
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	ns	ns	ns
Orthogonal Contrasts for N rate			
rate	ns	ns	ns
linear	0.07	ns	0.06
quadratic	ns	ns	ns

[z] annual estimates include the growing season and fall of 2001 plus spring thaw 2002.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 52. Estimates of seasonal and annual (May 2002-April 2003) N_2O losses measured at Star City, and significance levels for selected treatment contrasts.

Treatment	**Frost-free 2002**	**Spring 2003**	**Annual** [z]
	grams N ha^{-1}		
AA Fall band	372	258	631
AA Side-row band	255	128	383
AA Mid-row band	383	107	491
Urea Fall band	358	216	574
Urea Side-row band	208	120	328
Urea Mid-row band (0.5x rate)	176	119	295
Urea Mid-row band	239	98	337
Urea Mid-row band (1.5x rate)	245	155	399
Urea broadcast	883	73	955
Check (no N applied)	167	79	246
Contrasts	**Significance**		
N applied vs. no N applied	< 0.01	ns	< 0.01
Fall banded N vs. Spring banded N	0.05	0.03	0.01
Mid-row vs. Side-row banded N	ns	ns	ns
NH3 vs. Urea	ns	ns	ns
Urea broadcast vs. Urea spring band	< 0.01	ns	< 0.01
Orthogonal Contrasts for N rate			
rate	ns	ns	ns
linear	0.07	ns	0.06
quadratic	ns	ns	ns

[z] annual estimates include the growing season and fall of 2002 plus spring thaw 2003.

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 53. Estimated 3-year cumulative (May 2000-April 2003) N_2O loss at four sites in Saskatchewan, and significance levels for selected treatment contrasts.

Treatment	**Swift Current**	**Scott**	**Indian Head**	**Star City**
	grams N ha^{-1}			
AA Fall band	624	484	287	1064
AA Side-row band	699	420	313	863
AA Mid-row band	807	625	218	1280
Urea Fall band	947	451	365	1268
Urea Side-row band	563	264	225	515
Urea Mid-row band (0.5x rate)	521	336	151	767
Urea Mid-row band	879	443	246	856
Urea Mid-row band (1.5x rate)	1327	861	210	848
Urea broadcast	761	507	406	1290
Check (no N applied)	381	180	100	884
Contrasts	**Significance**			
N applied vs. no N applied	0.07	0.02	<0.01	ns
Fall banded N vs. Spring banded N	ns	ns	ns	0.02
Mid-row vs. Side-row banded N	ns	0.07	ns	<0.01
NH3 vs. Urea	ns	ns	ns	0.09
Urea broadcast vs. Urea spring band	ns	ns	0.02	<0.01
Orthogonal Contrasts for N rate				
rate	<0.01	<0.01	<0.01	ns
linear	<0.01	<0.01	<0.01	ns
quadratic	ns	ns	ns	ns

[Y] not significant at $p > 0.1$, values presented are actual probability levels

Table 54. Estimated percentage of fertilizer-N lost as N_2O-N at Swift Current.

Treatment	2000/2001	2001/2002	2000/2003	Mean (3-year)
		%		
AA Fall band	0.1	0.1	0.3	0.2
AA Side-row band	0.0	0.2	0.4	0.2
AA Mid-row band	0.3	0.2	0.2	0.3
Urea Fall band	0.2	0.0	0.8	0.4
Urea Side-row band	0.1	0.1	0.1	0.1
Urea Mid-row band (0.5x rate)	0.1	0.2	0.3	0.2
Urea Mid-row band	0.3	0.2	0.4	0.3
Urea Mid-row band (1.5x rate)	0.5	0.3	0.3	0.4
Urea broadcast	0.3	0.1	0.2	0.2

Table 55. Estimated percentage of fertilizer-N lost as N_2O-N at Scott.

Treatment	2000/2001	2001/2002	2000/2003	Mean (3-year)
		%		
AA Fall band	0.2	0.2	0.2	0.2
AA Side-row band	0.1	0.1	0.1	0.1
AA Mid-row band	0.2	0.3	0.4	0.3
Urea Fall band	0.3	0.1	0.1	0.2
Urea Side-row band	0.1	0.0	0.0	0.1
Urea Mid-row band (0.5x rate)	0.1	0.4	0.1	0.2
Urea Mid-row band	0.0	0.1	0.2	0.1
Urea Mid-row band (1.5x rate)	0.1	0.4	0.3	0.3
Urea broadcast	0.1	0.1	0.5	0.2

Table 56. Estimated percentage of fertilizer-N lost as N_2O-N at Indian Head.

Treatment	2000/2001	2001/2002	2000/2003	Mean (3-year)
		%		
AA Fall band	0.2	0.1	0.0	0.1
AA Side-row band	0.2	0.1	0.1	0.1
AA Mid-row band	0.1	0.1	0.0	0.1
Urea Fall band	0.2	0.1	0.1	0.1
Urea Side-row band	0.1	0.1	0.1	0.1
Urea Mid-row band (0.5x rate)	0.1	0.0	0.0	0.1
Urea Mid-row band	0.1	0.0	0.0	0.1
Urea Mid-row band (1.5x rate)	0.0	0.0	0.1	0.0
Urea broadcast	0.1	0.2	0.1	0.1

Table 57. Estimated percentage fertilizer-N lost as N_2O-N at Star City.

Treatment	2000/2001	2001/2002	2000/2003	Mean (2-year) [Y]
		%		
AA Fall band	-0.3 [Z]	0.0	0.5	0.3
AA Side-row band	-0.2	0.0	0.2	0.1
AA Mid-row band	0.2	0.0	0.3	0.2
Urea Fall band	0.1	0.0	0.5	0.2
Urea Side-row band	-0.6	0.0	0.1	0.1
Urea Mid-row band (0.5x rate)	-0.5	0.0	0.1	0.1
Urea Mid-row band	-0.2	0.0	0.1	0.1
Urea Mid-row band (1.5x rate)	-0.2	0.0	0.1	0.1
Urea broadcast	-0.4	0.0	1.0	0.5

[Z] Negative values resulted from an unusually high loss from the check treatment during spring.

[Y] Means based on 2001-2002 and 2002-2003 annual cycles.

Table 58. Gross energy production (MJ ha^{-1}) and crop yield (t ha^{-1}) (in parentheses) for wheat, canola and flaxseed at four sites in 2000. Side banding with urea (1.0 X N rate) in spring.

Location	Wheat		Canola		Flaxseed	
Indian Head (Black)	40,442	(2.34)	62,826	(2.14)	39,243	(1.60)
Star City (Dark Gray)	37,027	(2.11)	67,233	(2.29)	45,738	(1.82)
Scott (Dark Brown)	38,005	(2.17)	36,663	(1.25)	53,142	(2.11)
Swift Current (Brown)	78,063	(3.80)	48,074	(1.56)	40,990	(1.56)

Table 59. Gross energy production (MJ ha^{-1}) and crop yield (t ha^{-1})(in parentheses) for wheat, canola and flaxseed at four sites in 2001. Side banding with urea (1.0 x N rate) in spring.

Location	Wheat		Canola		Flaxseed	
Indian Head (Black)	37,514	(2.14)	37,045	(1.26)	27,110	(1.11)
Star City (Dark Gray)	15,272	(0.95)	23,213	(0.79)	28,325	(1.15)
Scott (Dark Brown)	20,286	(0.73)	21,204	(0.73)	28,565	(1.16)
Swift Current (Brown)	11,451	(0.70)	14,840	(0.51)	16,712	(0.71)

Table 60. Gross energy production (MJ ha^{-1}) and crop yield (t ha^{-1}) (in parentheses) for wheat, canola and flaxseed at four sites in 2002. Side banding with NH_3 (1.0 X N rate) in spring.

Location	Wheat		Canola		Flaxseed	
Indian Head (Black)	41323	(2.34)	46105	(1.57)	48174	(1.92)
Star City (Dark Gray)	1445	(0.27)	50478	(1.72)	22140	(0.92)
Scott (Dark Brown)	779	(0.18)	8020	(0.28)	4487	(0.24)
Swift Current (Brown)	34293	(1.92)	34986	(1.19)	28390	(1.16)

Table 61. Effect of drought on energy performance factors for canola at the Star City site. Comparison of the year 2000 and the year 2001 (drought in 2001).

Energy factor determined	2000	2001
Gross energy output (MJ ha^{-1})	67,233	23,213
Total energy input (MJ ha^{-1})	9,644	8,744
Net energy output (MJ ha^{-1})	57,589	14,469
Grain Yield (kg ha^{-1})	2,290	790
Grain/unit of input energy (kg GJ^{-1})	237	91
Output/input ratio	7.0	2.7

Table 62. *Effect of drought on energy performance factors for wheat at the Swift Current site. Comparison of 2000 with 2001 (drought in 2001). Data from a single treatment (recommended rate of side-banded urea app1ied in spring) is shown.*

Energy factor measured	2000	2001
Gross energy output (MJ ha^{-1})	78,063	11,451
Total energy input (MJ ha^{-1})	7,666	6,674
Net energy output (MJ ha^{-1})	70,397	4,776
Yield (kg ha^{-1})	3,803	700
Grain/unit of energy input (kg GJ^{-1})	556	105
Output/input ratio	10.2	1.7

Table 63. Non-renewable energy input, energy output, and energy use efficiency of canola at the Indian Head site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	------------	------------	----(MJ ha^{-1})----	------------			(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1460	6182	64393	58211	10.3	350
Urea side band, 1.0 × N	7245	1449	9193	62826	53632	6.8	231
Urea side band, 1.5 × N	10270	1563	12359	79123	66763	66.4	217
Urea mid-row band, 0.5 × N	4220	1348	6058	60589	54531	10.0	340
Urea mid-row band, 1.0 × N	7245	1479	9245	79373	70127	8.6	292
Urea mid-row band, 1.5 × N	10270	1526	12329	86156	73827	7.0	238
Urea fall band, 1.0 × N	7245	1952	9821	100114	90293	10.2	347
Urea spring broadcast, 1.0 × N	7245	1427	9165	59588	50423	6.5	220
NH_3 side band, 0.5 × N	3283	1420	5210	68322	63111	12.8	434
NH_3 side band, 1.0 × N	5371	1415	7293	67637	60345	9.2	313
NH_3 side band, 1.5 × N	7460	1538	9534	85303	75769	8.9	304
NH_3 mid-row band, 0.5 × N	3283	1358	5133	59419	54286	11.5	390
NH_3 mid-row band, 1.0 × N	5371	1385	7256	63319	56063	8.7	297
NH_3 mid -row band, 1.5 × N	7460	1394	9355	64606	55251	6.9	233
NH_3 fall band, 1.0 × N	5371	1798	7755	72118	64363	9.3	316
Side band, no N	1194	1428	3132	72096	68964	22.6	769
Urea side band, 1.0 × N, seed-placed P	7245	1543	9325	88592	79267	9.5	323
Mean	6177	1499	8138	72563	64425	9.7	330
LSD (0.05)			258	29919	29661	4.5	153
Significance							
Treatment			**	0.24	0.39	**	**
Spring band: Urea vs. NH_3			**	0.52	0.74	0.11	0.11
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.07	0.09	0.69	0.69
Spring band: Side band vs. mid-row band			0.22	0.70	0.71	0.75	0.75
No vs. all other treatments			**	0.96	0.66	**	**
Spring band: 0 vs. 0.5 × N			**	0.45	0.33	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.50	0.74	*	*
Spring band: 1.0 × vs. 1.5 × N			**	0.16	0.29	0.36	0.36
Fall band vs. spring band (1.0 × N)			**	0.06	0.06	0.30	0.30
Urea: broadcast vs. band (1.0 × N)			*	0.09	0.09	0.27	0.27
Urea: side band vs. side band +P (1.0 × N)			0.31	0.09	0.09	0.23	0.23

Table 64. Non-renewable energy input, energy output, and energy use efficiency of flax at the Indian Head site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
			(MJ ha^{-1})				(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1406	6393	41484	35090	6.5	260
Urea side band, 1.0 × N	7245	1385	9393	39243	29849	4.2	167
Urea side band, 1.5 × N	10270	1374	12405	38061	25655	3.1	123
Urea mid-row band, 0.5 × N	4220	1316	6298	41061	34763	6.5	261
Urea mid-row band, 1.0 × N	7245	1311	9317	40561	31244	4.4	174
Urea mid-row band, 1.5 × N	10270	1299	12328	39223	26896	3.2	128
Urea fall band, 1.0 × N	7245	1625	9694	38808	29113	4.0	161
Urea spring broadcast, 1.0 × N	7245	1397	9408	40555	31147	4.3	173
NH_3 side band, 0.5 × N	3283	1316	5361	39061	33700	7.3	292
NH_3 side band, 1.0 × N	5371	1295	7425	36859	29435	5.0	199
NH_3 side band, 1.5 × N	7460	1291	9508	36385	26877	3.8	154
NH_3 mid-row band, 0.5 × N	3283	1313	5358	38827	33469	7.2	291
NH_3 mid-row band, 1.0 × N	5371	1312	7445	38684	31239	5.2	208
NH_3 mid -row band, 1.5 × N	7460	1319	9541	39386	29844	4.1	165
NH_3 fall band, 1.0 × N	5371	1680	7889	40522	32633	5.1	206
Side band, no N	1194	1263	3208	35287	32080	11.0	443
Urea side band, 1.0 × N, seed-placed P	7245	1276	9274	36677	27403	4.0	159
Mean	6117	1363	8250	38864	30614	5.2	238
LSD (0.05)			48	4238	4190	0.6	22
Significance							
Treatment			**	0.19	**	**	**
Spring band: Urea vs. NH_3			**	*	0.84	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.42	0.10	**	**
Spring band: Side band vs. mid-row band			**	0.20	0.19	0.25	0.25
No vs. all other treatments			**	*	0.31	**	**
Spring band: 0 vs. 0.5 × N			**	**	0.19	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.23	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.59	**	**	**
Fall band vs. spring band (1.0 × N)			**	0.52	0.74	0.55	0.52
Urea: broadcast vs. band (1.0 × N)			**	0.56	0.53	0.57	0.57
Urea: side band vs. side band +P (1.0 × N)			**	0.23	0.25	0.44	0.44

Table 65. Non-renewable energy input, energy output, and energy use efficiency of wheat at the Indian Head site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	----------	----------	(MJ ha^{-1})	----------			(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1262	5926	37621	31695	6.3	362
Urea side band, 1.0 × N	7245	1279	8974	40442	31468	4.5	256
Urea side band, 1.5 × N	10270	1285	12007	41438	29431	3.5	196
Urea mid-row band, 0.5 × N	4220	1172	5830	36962	31132	6.3	362
Urea mid-row band, 1.0 × N	7245	1181	8867	38458	29591	4.3	247
Urea mid-row band, 1.5 × N	10270	1178	11889	38056	26167	3.2	182
Urea fall band, 1.0 × N	7245	1521	9278	40175	30897	4.3	246
Urea spring broadcast, 1.0 × N	7245	1290	8988	42186	33198	4.7	266
NH_3 side band, 0.5 × N	3283	1181	4904	35619	30715	7.3	415
NH_3 side band, 1.0 × N	5371	1189	7003	36849	29847	5.3	300
NH_3 side band, 1.5 × N	7460	1190	9093	37111	28018	4.1	233
NH_3 mid-row band, 0.5 × N	3283	1161	4878	32326	27449	6.6	381
NH_3 mid-row band, 1.0 × N	5371	1200	7017	38655	31638	5.5	313
NH_3 mid -row band, 1.5 × N	7460	1209	9117	40077	30960	4.4	250
NH_3 fall band, 1.0 × N	5371	1543	7430	37289	29859	5.0	286
Side band, no N	1194	1078	2682	21891	19208	8.2	486
Urea side band, 1.0 × N, seed-placed P	7245	1202	8894	41826	32932	4.7	266
Mean	6117	1242	7810	37470	29659	5.2	297
LSD (0.05)			38	4709	4671	0.7	38
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	*	0.88	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.22	0.66	*	*
Spring band: Side band vs. mid-row band			**	0.43	0.46	0.56	0.57
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	**	**
Spring band: 0.5 × vs. 1.0 × N			**	*	0.74	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.63	0.09	**	**
Fall band vs. spring band (1.0 × N)			**	0.93	0.86	0.29	0.26
Urea: broadcast vs. band (1.0 × N)			**	0.20	0.19	0.30	0.30
Urea: side band vs. side band +P (1.0 × N)			**	0.56	0.53	0.58	0.58

Table 65. Non-renewable energy input, energy output, and energy use efficiency of wheat at the Indian Head site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	(MJ ha^{-1})						($kg\ GJ^{-1}$)
Urea side band, 0.5 × N	4220	1262	5926	37621	31695	6.3	362
Urea side band, 1.0 × N	7245	1279	8974	40442	31468	4.5	256
Urea side band, 1.5 × N	10270	1285	12007	41438	29431	3.5	196
Urea mid-row band, 0.5 × N	4220	1172	5830	36962	31132	6.3	362
Urea mid-row band, 1.0 × N	7245	1181	8867	38458	29591	4.3	247
Urea mid-row band, 1.5 × N	10270	1178	11889	38056	26167	3.2	182
Urea fall band, 1.0 × N	7245	1521	9278	40175	30897	4.3	246
Urea spring broadcast, 1.0 × N	7245	1290	8988	42186	33198	4.7	266
NH_3 side band, 0.5 × N	3283	1181	4904	35619	30715	7.3	415
NH_3 side band, 1.0 × N	5371	1189	7003	36849	29847	5.3	300
NH_3 side band, 1.5 × N	7460	1190	9093	37111	28018	4.1	233
NH_3 mid-row band, 0.5 × N	3283	1161	4878	32326	27449	6.6	381
NH_3 mid-row band, 1.0 × N	5371	1200	7017	38655	31638	5.5	313
NH_3 mid -row band, 1.5 × N	7460	1209	9117	40077	30960	4.4	250
NH_3 fall band, 1.0 × N	5371	1543	7430	37289	29859	5.0	286
Side band, no N	1194	1078	2682	21891	19208	8.2	486
Urea side band, 1.0 × N, seed-placed P	7245	1202	8894	41826	32932	4.7	266
Mean	6117	1242	7810	37470	29659	5.2	297
LSD (0.05)			38	4709	4671	0.7	38
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	*	0.88	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.22	0.66	*	*
Spring band: Side band vs. mid-row band			**	0.43	0.46	0.56	0.57
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	**	**
Spring band: 0.5 × vs. 1.0 × N			**	*	0.74	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.63	0.09	**	**
Fall band vs. spring band (1.0 × N)			**	0.93	0.86	0.29	0.26
Urea: broadcast vs. band (1.0 × N)			**	0.20	0.19	0.30	0.30
Urea: side band vs. side band +P (1.0 × N)			**	0.56	0.53	0.58	0.58

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 66. Non-renewable energy input, energy output, and energy use efficiency of canola at the Indian Head site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	-----	-----	(MJ ha^{-1})	-----			(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1270	6356	37001	30645	5.8	198
Urea side band, 1.0 × N	7245	1270	9382	37045	27663	3.9	135
Urea side band, 1.5 × N	10270	1250	12381	34095	21713	2.7	94
Urea mid-row band, 0.5 × N	4220	1300	6410	53724	47315	8.4	286
Urea mid-row band, 1.0 × N	7245	1324	9464	57138	47674	6.0	205
Urea mid-row band, 1.5 × N	10270	1324	12489	57102	44612	4.6	156
Urea fall band, 1.0 × N	7245	1698	9917	63598	53682	6.4	218
Urea spring broadcast, 1.0 × N	7245	1402	9546	56042	46497	5.9	200
NH_3 side band, 0.5 × N	3283	1061	5176	16790	11613	3.2	111
NH_3 side band, 1.0 × N	5371	1096	7307	21712	14405	3.0	102
NH_3 side band, 1.5 × N	7460	1080	9376	19497	10121	2.1	71
NH_3 mid-row band, 0.5 × N	3283	1256	5418	44807	39389	8.3	282
NH_3 mid-row band, 1.0 × N	5371	1317	7581	53474	45893	7.0	240
NH_3 mid -row band, 1.5 × N	7460	1308	9659	52253	42594	5.4	184
NH_3 fall band, 1.0 × N	5371	1695	8038	57352	49314	7.1	243
Side band, no N	1194	1135	3179	29982	26802	9.4	322
Urea side band, 1.0 × N, seed-placed P	7245	1236	9355	44483	35128	4.8	162
Mean	6117	1295	8296	43300	35003	5.5	189
LSD (0.05)			72	8350	8278	1.0	33
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	**	**	*	*
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.14	0.29	0.14	0.14
Spring band: Side band vs. mid-row band			**	**	**	**	**
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	*	0.10	**	**
Spring band: 0.5 × vs. 1.0 × N			**	*	0.42	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.44	*	**	**
Fall band vs. spring band (1.0 × N)			**	**	**	**	**
Urea: broadcast vs. band (1.0 × N)			0.16	0.31	0.30	0.30	0.30
Urea: side band vs. side band +P (1.0 × N)			0.46	0.08	0.08	0.10	0.10

*, ** Significant at *P<0.05* and *P<0.01* probability levels, respectively. Other probabilities given.

Table 67. Non-renewable energy input, energy output, and energy use efficiency of flax at the Indian Head site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	----------	----------	(MJ ha^{-1})	----------			($kg\ GJ^{-1}$)
Urea side band, 0.5 × N	4220	1252	6142	29228	23085	4.8	193
Urea side band, 1.0 × N	7245	1233	9144	27110	17967	3.0	121
Urea side band, 1.5 × N	10270	1254	12195	29416	17221	2.4	98
Urea mid-row band, 0.5 × N	4220	1173	6059	29877	23818	4.9	200
Urea mid-row band, 1.0 × N	7245	1165	9075	29046	19971	3.3	130
Urea mid-row band, 1.5 × N	10270	1164	12099	28994	16895	2.4	97
Urea fall band, 1.0 × N	7245	1475	9447	26889	17442	2.8	116
Urea spring broadcast, 1.0 × N	7245	1235	9146	27344	18198	3.0	122
NH_3 side band, 0.5 × N	3283	1191	5144	29903	24759	5.8	236
NH_3 side band, 1.0 × N	5371	1187	7228	29513	22285	4.1	166
NH_3 side band, 1.5 × N	7460	1230	9369	34170	24801	3.6	147
NH_3 mid-row band, 0.5 × N	3283	1179	5130	28649	23519	5.6	227
NH_3 mid-row band, 1.0 × N	5371	1123	7150	22505	15356	3.1	130
NH_3 mid -row band, 1.5 × N	7460	1160	9283	26487	17204	2.9	117
NH_3 fall band, 1.0 × N	5371	1550	7666	30773	23107	4.0	163
Side band, no N	1194	1134	2986	25616	22631	8.6	351
Urea side band, 1.0 × N, seed-placed P	7245	1166	9076	29195	20119	3.2	131
Mean	6117	1228	8020	28513	20493	4.0	161
LSD (0.05)			67	5993	5925	0.7	28
Significance							
Treatment			**	0.19	*	**	**
Spring band: Urea vs. NH_3			**	0.74	0.22	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.20	0.06	**	**
Spring band: Side band vs. mid-row band			**	0.07	0.07	0.08	0.08
No vs. all other treatments			**	0.16	0.30	**	**
Spring band: 0 vs. 0.5 × N			**	0.11	0.62	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.12	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.07	0.93	**	**
Fall band vs. spring band (1.0 × N)			**	0.33	0.45	0.71	0.75
Urea: broadcast vs. band (1.0 × N)			**	0.89	0.91	0.95	0.95
Urea: side band vs. side band +P (1.0 × N)			*	0.49	0.47	0.49	0.48

*, ** Significant at *P<0.05* and *P<0.01* probability levels, respectively. Other probabilities given.

Table 68. Non-renewable energy input, energy output, and energy use efficiency of wheat at the Indian Head site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	-----------------	-----------------	(MJ ha^{-1})	-----------------			(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1239	6305	34019	27714	5.4	309
Urea side band, 1.0 × N	7245	1261	9359	37514	28155	4.0	229
Urea side band, 1.5 × N	10270	1263	12386	37785	25399	3.0	174
Urea mid-row band, 0.5 × N	4220	1141	6199	32139	25940	5.2	299
Urea mid-row band, 1.0 × N	7245	1161	9249	35203	25954	3.8	218
Urea mid-row band, 1.5 × N	10270	1154	12266	34169	21903	2.8	160
Urea fall band, 1.0 × N	7245	1484	9638	34267	24629	3.6	204
Urea spring broadcast, 1.0 × N	7245	1213	9296	29768	20472	3.2	185
NH_3 side band, 0.5 × N	3283	1163	5289	32640	27351	6.2	355
NH_3 side band, 1.0 × N	5371	1166	7382	33243	25861	4.5	259
NH_3 side band, 1.5 × N	7460	1164	9467	32897	23429	3.5	200
NH_3 mid-row band, 0.5 × N	3283	1140	5259	28986	23728	5.5	320
NH_3 mid-row band, 1.0 × N	5371	1154	7366	31292	23926	4.2	245
NH_3 mid -row band, 1.5 × N	7460	1171	9477	34062	24585	3.6	206
NH_3 fall band, 1.0 × N	5371	1514	7800	32607	24807	4.2	240
Side band, no N	1194	1102	3123	25848	22725	8.3	485
Urea side band, 1.0 × N, seed-placed P	7245	1147	9231	33009	23778	3.6	206
Mean	6117	1214	8182	32909	24726	4.4	253
LSD (0.05)			31	3834	3803	0.6	29
Significance							
Treatment			**	**	*	**	**
Spring band: Urea vs. NH_3			**	**	0.19	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.39	0.93	*	*
Spring band: Side band vs. mid-row band			**	*	*	*	*
No vs. all other treatments			**	**	0.13	**	**
Spring band: 0 vs. 0.5 × N			**	**	*	**	**
Spring band: 0.5 × vs. 1.0 × N			**	*	0.83	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.67	*	**	**
Fall band vs. spring band (1.0 × N)			**	0.46	0.28	0.11	0.09
Urea: broadcast vs. band (1.0 × N)			**	**	**	*	*
Urea: side band vs. side band +P (1.0 × N)			**	*	*	0.12	0.12

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 69. Nonrenewable energy input, energy output and energy use efficiency of canola at Indian Head 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	---------------------	---------------------	MJ ha^{-1})	---------------------			
Treatment							
Urea side band, 0.5 × N	4220	1299	6137	35230	29093	5.7	196
Urea side band, 1.0 × N	7245	1245	9096	27571	18475	3.0	104
Urea side band, 1.5 × N	10270	1366	12271	44919	32648	3.7	125
Urea mid-row band, 0.5 × N	4220	1170	5993	29096	23103	4.8	165
Urea mid-row band, 1.0 × N	7245	1244	9110	39738	30628	4.4	149
Urea mid-row band, 1.5 × N	10270	1231	12120	37898	25778	3.1	107
Urea fall band, 1.0 × N	7245	1562	9493	38130	28636	4.0	137
Urea spring broadcast, 1.0 × N	7245	1331	9202	39857	30655	4.3	148
NH_3 side band, 0.5 × N	3283	1206	5101	31674	26573	6.2	212
NH_3 side band, 1.0 × N	5371	1306	7314	46105	38791	6.3	214
NH_3 side band, 1.5 × N	7460	1321	9421	48265	38844	5.1	175
NH_3 mid-row band, 0.5 × N	3283	1196	5089	30299	25210	6.0	203
NH_3 mid-row band, 1.0 × N	5371	1270	7269	40886	33617	5.6	192
NH_3 mid -row band, 1.5 × N	7460	1288	9379	43459	34079	4.6	158
NH_3 fall band, 1.0 × N	5371	1605	7671	38475	30804	5.0	171
Side band, no N	1194	1155	2950	26980	24030	9.1	310
Urea side band, 1.0 × N, seed-placed P	7245	1331	9218	52260	43042	5.7	193
Mean	6117	1302	8049	38285	30236	5.1	174
LSD (0.05)			109	12674	12565	1.8	62
Significance							
Treatment			**	**	*	**	**
Spring band: Urea vs. NH_3			**	0.1	*	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.96	0.73	0.28	0.28
Spring band: Side band vs. mid-row band			**	0.43	0.44	0.50	0.50
No vs. all other treatments			**	**	0.15	**	**
Spring band: 0 vs. 0.5 × N			**	0.36	0.69	**	**
Spring band: 0.5 × vs. 1.0 × N			**	*	0.17	0.06	0.06
Spring band: 1.0 × vs. 1.5 × N			**	0.11	0.44	0.13	0.13
Fall band vs. spring band (1.0 × N)			**	0.94	0.86	0.58	0.57
Urea: broadcast vs. band (1.0 × N)			0.48	0.36	0.36	0.48	0.48
Urea: side band vs. side band +P (1.0 × N)			*	**	**	**	**

Table 70. Nonrenewable energy input, energy output and energy use efficiency of flax at Indian Head 2002

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	--------	--------	MJ ha^{-1}	--------			
Urea side band, 0.5 × N	4220	1423	6360	47854	41495	7.5	299
Urea side band, 1.0 × N	7245	1425	9388	48095	38708	5.1	204
Urea side band, 1.5 × N	10270	1477	12476	53750	41274	4.3	171
Urea mid-row band, 0.5 × N	4220	1371	6310	51534	45224	8.2	324
Urea mid-row band, 1.0 × N	7245	1368	9332	51219	41887	5.5	218
Urea mid-row band, 1.5 × N	10270	1380	12373	52600	40228	4.3	169
Urea fall band, 1.0 × N	7245	1655	9676	46584	36908	4.8	192
Urea spring broadcast, 1.0 × N	7245	1460	9431	51956	42525	5.5	219
NH_3 side band, 0.5 × N	3283	1381	5386	50658	45273	9.4	374
NH_3 side band, 1.0 × N	5371	1358	7446	48174	40728	6.5	257
NH_3 side band, 1.5 × N	7460	1363	9541	48758	39217	5.1	203
NH_3 mid-row band, 0.5 × N	3283	1395	5404	52285	46881	9.7	384
NH_3 mid-row band, 1.0 × N	5371	1391	7487	51752	44266	6.9	274
NH_3 mid -row band, 1.5 × N	7460	1377	9559	50306	40747	5.3	209
NH_3 fall band, 1.0 × N	5371	1685	7840	45523	37683	5.8	231
Side band, no N	1194	1263	3153	39813	36660	12.6	505
Urea side band, 1.0 × N, seed-placed P	7245	1321	9274	46074	36800	5.0	198
Mean	6117	1417	8261	49232	40971	6.5	261
LSD (0.05)			69	6103	6034	0.8	33
Significance							
Treatment			**	**	*	**	**
Spring band: Urea vs. NH_3			**	0.68	0.26	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.73	0.80	*	*
Spring band: Side band vs. mid-row band			0.12	0.10	0.09	0.09	0.08
No vs. all other treatments			**	**	*	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.62	*	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.31	0.50	**	**
Fall band vs. spring band (1.0 × N)			**	*	*	*	**
Urea: broadcast vs. band (1.0 × N)			0.22	0.19	0.18	0.29	0.29
Urea: side band vs. side band +P (1.0 × N)			**	0.51	0.53	0.71	0.72

Table 71. Nonrenewable energy input, energy output and energy use efficiency of wheat at Indian Head 2002

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	MJ ha^{-1}						
Urea side band, 0.5 × N	4220	1236	5846	40089	34242	6.9	389
Urea side band, 1.0 × N	7245	1244	8882	41323	32442	4.7	264
Urea side band, 1.5 × N	10270	1245	11908	41512	29603	3.5	198
Urea mid-row band, 0.5 × N	4220	1140	5742	38426	32684	6.7	381
Urea mid-row band, 1.0 × N	7245	1145	8774	39276	30502	4.5	254
Urea mid-row band, 1.5 × N	10270	1148	11804	39802	27999	3.4	192
Urea fall band, 1.0 × N	7245	1473	9170	39151	29981	4.3	243
Urea spring broadcast, 1.0 × N	7245	1242	8880	41108	32228	4.6	262
NH_3 side band, 0.5 × N	3283	1176	4851	41287	36436	8.5	482
NH_3 side band, 1.0 × N	5371	1175	6938	41188	34249	5.9	337
NH_3 side band, 1.5 × N	7460	1187	9042	43105	34063	4.8	270
NH_3 mid-row band, 0.5 × N	3283	1141	4806	35770	30964	7.4	426
NH_3 mid-row band, 1.0 × N	5371	1164	6924	39472	32548	5.7	324
NH_3 mid -row band, 1.5 × N	7460	1169	9020	40312	31292	4.5	254
NH_3 fall band, 1.0 × N	5371	1498	7325	36610	29285	5.0	285
Side band, no N	1194	1099	2664	31881	29217	12.0	690
Urea side band, 1.0 × N, seed-placed P	7245	1151	8782	40211	31429	4.6	260
Mean	6117	1214	7727	39443	31716	5.7	324
LSD (0.05)			34	4217	4183	0.5	29
Significance							
Treatment			**	**	*	**	**
Spring band: Urea vs. NH_3			**	0.89	*	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.23	0.74	**	**
Spring band: Side band vs. mid-row band			**	**	**	**	**
No vs. all other treatments			**	**	0.09	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.18	0.28	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.41	0.11	**	**
Fall band vs. spring band (1.0 × N)			**	0.06	*	**	**
Urea: broadcast vs. band (1.0 × N)			**	0.49	0.46	0.48	0.48
Urea: side band vs. side band +P (1.0 × N)			**	0.60	0.63	0.79	0.80

Table 72. Annual and 3-year mean energy performance factors (mean of all treatments) and seed yields for three crops and three years at Indian Head.

Energy factor determined	**2000**	**2001**	**2002**	**Mean**
Canola				
Seed Yield (Mg ha^{-1})	2.47	1.53	1.31	1.77
Gross energy output (MJ ha^{-1})	72563	43300	38285	51383
Net energy output (MJ ha^{-1})	64425	35003	30236	43221
Grain/unit of input energy (kg GJ^{-1})	330	189	174	231
Output/input ratio	9.7	5.5	5.1	6.8
Flax				
Seed Yield (Mg ha^{-1})	1.61	1.20	1.96	1.59
Gross energy output (MJ ha^{-1})	38864	28513	49232	38870
Net energy output (MJ ha^{-1})	30614	20493	40971	30693
Grain/unit of input energy (kg GJ^{-1})	238	161	261	220
Output/input ratio	5.2	4.0	6.5	5.2
Wheat				
Seed Yield (Mg ha^{-1})	2.22	1.97	2.24	2.14
Gross energy output (MJ ha^{-1})	37470	32909	39443	36607
Net energy output (MJ ha^{-1})	29659	24726	31716	28700
Grain/unit of input energy (kg GJ^{-1})	297	253	324	291
Output/input ratio	5.2	4.4	5.7	5.1

Table 73. Non-renewable energy input, energy output, and energy use efficiency of canola at the Star City site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	(MJ ha^{-1})						(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1493	6634	69072	62438	10.4	354
Urea side band, 1.0 × N	7245	1480	9644	67233	57589	7.0	237
Urea side band, 1.5 × N	10270	1472	12659	66092	53433	5.2	178
Urea mid-row band, 0.5 × N	4220	1367	6494	63333	56839	9.8	332
Urea mid-row band, 1.0 × N	7245	1333	9476	58367	48891	6.2	210
Urea mid-row band, 1.5 × N	10270	1459	12658	76474	63816	6.0	206
Urea fall band, 1.0 × N	7245	1756	9990	71883	61893	7.2	245
Urea spring broadcast, 1.0 × N	7245	1505	9674	70742	61068	7.3	249
NH_3 side band, 0.5 × N	3283	1376	5569	62061	56492	11.1	380
NH_3 side band, 1.0 × N	5371	1475	7780	76268	68488	9.8	334
NH_3 side band, 1.5 × N	7460	1462	9852	74370	64518	7.5	257
NH_3 mid-row band, 0.5 × N	3283	1414	5615	67476	61860	12.0	409
NH_3 mid-row band, 1.0 × N	5371	1473	7777	76003	68226	9.8	333
NH_3 mid -row band, 1.5 × N	7460	1483	9877	77349	67472	7.8	267
NH_3 fall band, 1.0 × N	5371	1735	8089	63061	54972	7.8	266
Side band, no N	1194	1274	3353	49950	46597	14.9	508
Urea side band, 1.0 × N, seed-placed P	7245	1458	9632	76400	66768	7.9	270
Mean	6117	1471	8516	68596	60080	8.7	296
LSD (0.05)			65	7536	7471	1.0	32
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	**	**	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	*	0.07	0.21	0.21
Spring band: Side band vs. mid-row band			**	0.67	0.65	0.69	0.69
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	**	**
Spring band: 0.5 × vs. 1.0 × N			**	*	0.46	**	**
Spring band: 1.0 × vs. 1.5 × N			**	*	0.42	**	**
Fall band vs. spring band (1.0 × N)			**	0.39	0.30	*	*
Urea: broadcast vs. band (1.0 × N)			0.27	0.11	0.11	0.17	0.17
Urea: side band vs. side band +P (1.0 × N)			0.72	*	*	*	*

*, ** Significant at *P<0.05* and *P<0.01* probability levels, respectively. Other probabilities given.

Table 74. Non-renewable energy input, energy output, and energy use efficiency of flax at the Star City site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	-------------	-------------	(MJ ha^{-1})	-------------			($kg\ GJ^{-1}$)
Urea side band, 0.5 × N	4220	1454	6848	46803	39955	6.8	272
Urea side band, 1.0 × N	7245	1444	9861	45738	35877	4.6	185
Urea side band, 1.5 × N	10270	1445	12887	45809	32922	3.6	142
Urea mid-row band, 0.5 × N	4220	1364	6751	46322	39571	6.9	273
Urea mid-row band, 1.0 × N	7245	1344	9751	44095	34343	4.5	180
Urea mid-row band, 1.5 × N	10270	1346	12780	44367	31588	3.5	139
Urea fall band, 1.0 × N	7245	1678	10155	44679	34524	4.4	176
Urea spring broadcast, 1.0 × N	7245	1425	9837	43620	33783	4.4	177
NH_3 side band, 0.5 × N	3283	1378	5832	45881	40049	7.9	314
NH_3 side band, 1.0 × N	5371	1385	7929	46673	38744	5.9	234
NH_3 side band, 1.5 × N	7460	1376	10007	45718	35711	4.6	182
NH_3 mid-row band, 0.5 × N	3283	1379	5833	45978	40145	7.9	314
NH_3 mid-row band, 1.0 × N	5371	1363	7902	44263	36361	5.6	224
NH_3 mid -row band, 1.5 × N	7460	1387	10020	46920	36900	4.7	186
NH_3 fall band, 1.0 × N	5371	1735	8351	46517	38166	5.6	222
Side band, no N	1194	1325	3678	42016	38338	11.4	457
Urea side band, 1.0 × N, seed-placed P	7245	1358	9769	45666	35897	4.7	186
Mean	6117	1423	8717	45357	36640	5.7	227
LSD (0.05)			30	2698	2668	0.4	14
Significance							
Treatment			**	*	**	**	**
Spring band: Urea vs. NH_3			**	0.49	**	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.18	**	**	**
Spring band: Side band vs. mid-row band			**	0.16	0.19	0.45	0.46
No vs. all other treatments			**	**	0.07	**	**
Spring band: 0 vs. 0.5 × N			**	**	0.14	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.12	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.45	**	**	**
Fall band vs. spring band (1.0 × N)			**	0.62	0.99	0.11	0.10
Urea: broadcast vs. band (1.0 × N)			**	0.27	0.30	0.56	0.57
Urea: side band vs. side band +P (1.0 × N)			**	0.96	0.99	0.84	0.83

Table 75. Non-renewable energy input, energy output, and energy use efficiency of wheat at the Star City site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	------------------	------------------	(MJ ha^{-1})	------------------			(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1233	6603	33107	26504	5.0	288
Urea side band, 1.0 × N	7245	1258	9660	37027	27367	3.8	219
Urea side band, 1.5 × N	10270	1285	12721	41377	28657	3.3	184
Urea mid-row band, 0.5 × N	4220	1157	6524	34562	28038	5.3	304
Urea mid-row band, 1.0 × N	7245	1191	9595	40156	30562	4.2	238
Urea mid-row band, 1.5 × N	10270	1224	12663	45414	32751	3.6	202
Urea fall band, 1.0 × N	7245	1524	9996	40662	30666	4.1	231
Urea spring broadcast, 1.0 × N	7245	1274	9682	39665	29984	4.1	233
NH_3 side band, 0.5 × N	3283	1150	5577	30563	24985	5.5	317
NH_3 side band, 1.0 × N	5371	1210	7745	40306	32561	5.2	295
NH_3 side band, 1.5 × N	7460	1221	9847	41999	32153	4.3	242
NH_3 mid-row band, 0.5 × N	3283	1152	5581	30960	25380	5.5	320
NH_3 mid-row band, 1.0 × N	5371	1188	7716	36728	29012	4.8	272
NH_3 mid -row band, 1.5 × N	7460	1234	9863	44048	34185	4.5	252
NH_3 fall band, 1.0 × N	5371	1537	8136	36368	28231	5.7	255
Side band, no N	1194	1057	3370	18649	15279	5.5	335
Urea side band, 1.0 × N, seed-placed P	7245	1194	9598	40498	30900	4.2	239
Mean	6117	1241	8522	37182	28660	4.5	260
LSD (0.05)			33	4047	4014	0.6	30
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	0.16	0.37	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	*	0.23	0.16	0.11
Spring band: Side band vs. mid-row band			**	0.14	0.12	0.26	0.25
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	0.37	*
Spring band: 0.5 × vs. 1.0 × N			**	**	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	**	*	**	**
Fall band vs. spring band (1.0 × N)			**	0.97	0.73	0.20	0.17
Urea: broadcast vs. band (1.0 × N)			**	0.82	0.73	0.77	0.76
Urea: side band vs. side band +P (1.0 × N)			**	0.09	0.08	0.17	0.17

*, ** Significant at $P<0.05$ and $P<0.01$ probability levels, respectively. Other probabilities given.

Table 76. Non-renewable energy input, energy output, and energy use efficiency of canola at the Star City site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	----------	----------	----(MJ ha^{-1})----	----------			($kg\ GJ^{-1}$)
Urea side band, 0.5 × N	4220	1115	5697	20682	14985	3.6	124
Urea side band, 1.0 × N	7245	1133	8744	23213	14469	2.7	91
Urea side band, 1.5 × N	10270	1136	11773	23618	11845	2.0	69
Urea mid-row band, 0.5 × N	4220	1015	5588	18607	13019	3.3	114
Urea mid-row band, 1.0 × N	7245	1015	8613	18563	9950	2.2	74
Urea mid-row band, 1.5 × N	10270	1052	11685	24000	12315	2.1	70
Urea fall band, 1.0 × N	7245	1363	9033	21300	12267	2.4	81
Urea spring broadcast, 1.0 × N	7245	1110	8715	19858	11143	2.3	78
NH_3 side band, 0.5 × N	3283	1006	4640	14737	10097	3.2	109
NH_3 side band, 1.0 × N	5371	1051	6785	21248	14464	3.1	107
NH_3 side band, 1.5 × N	7460	1064	8889	23088	14199	2.6	89
NH_3 mid-row band, 0.5 × N	3283	1027	4667	17813	13146	3.8	131
NH_3 mid-row band, 1.0 × N	5371	1027	6754	17724	10970	2.6	90
NH_3 mid -row band, 1.5 × N	7460	1047	8868	20630	11762	2.3	80
NH_3 fall band, 1.0 × N	5371	1393	7196	19880	12684	2.8	95
Side band, no N	1194	971	2509	12346	9837	4.9	169
Urea side band, 1.0 × N, seed-placed P	7245	1027	8629	20358	11730	2.4	81
Mean	6117	1091	7576	19863	12287	2.8	97
LSD (0.05)			37	4276	4239	0.6	20
Significance							
Treatment			**	**	0.32	**	**
Spring band: Urea vs. NH_3			**	*	0.71	*	*
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.51	0.84	0.17	0.16
Spring band: Side band vs. mid-row band			**	0.08	0.09	0.21	0.21
No vs. all other treatments			**	**	0.10	**	**
Spring band: 0 vs. 0.5 × N			**	**	0.08	**	**
Spring band: 0.5 × vs. 1.0 × N			**	*	0.74	**	**
Spring band: 1.0 × vs. 1.5 × N			**	*	0.95	**	**
Fall band vs. spring band (1.0 × N)			**	0.76	0.99	0.64	0.64
Urea: broadcast vs. band (1.0 × N)			**	0.51	0.53	0.64	0.64
Urea: side band vs. side band +P (1.0 × N)			**	0.19	0.20	0.31	0.31

*, ** Significant at $P<0.05$ and $P<0.01$ probability levels, respectively. Other probabilities given.

Table 77. Non-renewable energy input, energy output, and energy use efficiency of flax at the Star City site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	-------------------	-------------------	(MJ ha^{-1})	-------------------			(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1261	6161	30156	23996	4.9	199
Urea side band, 1.0 × N	7245	1244	9165	28325	19160	3.1	126
Urea side band, 1.5 × N	10270	1194	12128	22810	10682	1.9	78
Urea mid-row band, 0.5 × N	4220	1161	6053	28623	22571	4.7	192
Urea mid-row band, 1.0 × N	7245	1142	9055	26571	17516	2.9	120
Urea mid-row band, 1.5 × N	10270	1125	12059	24726	12667	2.0	84
Urea fall band, 1.0 × N	7245	1441	9414	23220	13806	2.5	102
Urea spring broadcast, 1.0 × N	7245	1240	9160	27825	18665	3.0	124
NH_3 side band, 0.5 × N	3283	1216	5183	32637	27454	6.3	254
NH_3 side band, 1.0 × N	5371	1168	7213	27402	20190	3.8	155
NH_3 side band, 1.5 × N	7460	1177	9312	28357	19045	3.0	124
NH_3 mid-row band, 0.5 × N	3283	1211	5178	32137	26960	6.2	251
NH_3 mid-row band, 1.0 × N	5371	1179	7226	28572	21346	4.0	161
NH_3 mid -row band, 1.5 × N	7460	1185	9322	29260	19938	3.1	128
NH_3 fall band, 1.0 × N	5371	1501	7614	25421	17808	3.3	137
Side band, no N	1194	1136	2997	25883	22886	8.6	353
Urea side band, 1.0 × N, seed-placed P	7245	1105	9009	22551	13541	2.5	103
Mean	6117	1217	8014	27322	19304	3.9	158
LSD (0.05)			51	4562	4510	0.5	21
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	**	**	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.34	0.08	**	**
Spring band: Side band vs. mid-row band			**	0.97	0.93	0.99	0.98
No vs. all other treatments			**	0.36	*	**	**
Spring band: 0 vs. 0.5 × N			**	**	0.19	**	**
Spring band: 0.5 × vs. 1.0 × N			**	**	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.21	**	**	**
Fall band vs. spring band (1.0 × N)			**	*	**	**	**
Urea: broadcast vs. band (1.0 × N)			*	0.34	0.32	0.35	0.35
Urea: side band vs. side band +P (1.0 × N)			**	*	*	*	*

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 78. Non-renewable energy input, energy output, and energy use efficiency of wheat at the Star City site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	(MJ ha^{-1})						(kg GJ^{-1})
Urea side band, 0.5 × N	4220	1071	5946	13597	7652	2.3	145
Urea side band, 1.0 × N	7245	1081	8984	15272	6288	1.7	106
Urea side band, 1.5 × N	10270	1099	12032	18097	6065	1.5	91
Urea mid-row band, 0.5 × N	4220	980	5849	12891	7042	2.2	140
Urea mid-row band, 1.0 × N	7245	988	8884	14051	5168	1.6	100
Urea mid-row band, 1.5 × N	10270	992	11914	14753	2838	1.2	77
Urea fall band, 1.0 × N	7245	1311	9273	13144	3871	1.4	90
Urea spring broadcast, 1.0 × N	7245	1077	8978	14542	5564	1.6	101
NH_3 side band, 0.5 × N	3283	1015	4956	15609	10652	3.1	195
NH_3 side band, 1.0 × N	5371	1022	7053	16605	9552	2.4	145
NH_3 side band, 1.5 × N	7460	1020	9139	16315	7176	1.8	110
NH_3 mid-row band, 0.5 × N	3283	1028	4972	17564	12592	3.5	216
NH_3 mid-row band, 1.0 × N	5371	1019	7049	16142	9093	2.3	141
NH_3 mid -row band, 1.5 × N	7460	1026	9147	17325	8178	1.9	116
NH_3 fall band, 1.0 × N	5371	1339	7432	11076	3645	1.5	98
Side band, no N	1194	967	2807	10814	8007	3.8	253
Urea side band, 1.0 × N, seed-placed P	7245	997	8896	15543	6648	1.7	108
Mean	6117	1061	7841	14903	7061	2.1	131
LSD (0.05)			33	4047	4014	0.7	37
Significance							
Treatment			**	*	**	**	**
Spring band: Urea vs. NH_3			**	*	**	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.31	0.91	0.84	0.69
Spring band: Side band vs. mid-row band			**	0.58	0.62	0.96	0.97
No vs. all other treatments			**	**	0.49	**	**
Spring band: 0 vs. 0.5 × N			**	*	0.35	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.55	0.06	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.28	0.15	*	*
Fall band vs. spring band (1.0 × N)			**	**	**	*	*
Urea: broadcast vs. band (1.0 × N)			**	0.82	0.78	0.85	0.85
Urea: side band vs. side band +P (1.0 × N)			**	0.89	0.86	0.89	0.89

Table 79. Nonrenewable energy input, energy output and energy use efficiency of canola at Star City 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	----------------	----------------	MJ ha^{-1}	----------------			
Treatment							
Urea side band, 0.5 × N	4220	1255	5890	40717	34827	6.9	236
Urea side band, 1.0 × N	7245	1344	9027	53622	44596	5.9	202
Urea side band, 1.5 × N	10270	1333	12038	52026	39988	4.3	147
Urea mid-row band, 0.5 × N	4220	1148	5773	37722	31949	6.5	223
Urea mid-row band, 1.0 × N	7245	1217	8884	47678	38794	5.4	183
Urea mid-row band, 1.5 × N	10270	1210	11901	46624	34724	3.9	133
Urea fall band, 1.0 × N	7245	1535	9267	46090	36823	5.0	169
Urea spring broadcast, 1.0 × N	7245	1238	8894	38289	29394	4.3	147
NH_3 side band, 0.5 × N	3283	1140	4827	34013	29186	7.0	240
NH_3 side band, 1.0 × N	5371	1255	7057	50478	43421	7.2	244
NH_3 side band, 1.5 × N	7460	1264	9157	51842	42685	5.7	193
NH_3 mid-row band, 0.5 × N	3283	1160	4851	36824	31973	7.6	259
NH_3 mid-row band, 1.0 × N	5371	1250	7051	49756	42705	7.1	241
NH_3 mid -row band, 1.5 × N	7460	1296	9197	56398	47201	6.1	209
NH_3 fall band, 1.0 × N	5371	1554	7416	43034	35618	5.8	198
Side band, no N	1194	998	2563	16242	13679	6.3	218
Urea side band, 1.0 × N, seed-placed P	7245	1214	8880	47222	38341	5.3	181
Mean	6117	1260	7804	44034	36230	5.9	201
LSD (0.05)			64	7482	7418	0.96	32
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	0.92	0.18	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.42	0.74	0.09	0.08
Spring band:.Side band vs. mid-row band			**	0.40	0.42	0.71	0.72
No vs. all other treatments			**	**	**	0.19	0.15
Spring band: 0 vs. 0.5 × N			**	**	**	0.08	0.09
Spring band: 0.5 × vs. 1.0 × N			**	**	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.47	0.51	**	**
Fall band vs. spring band (1.0 × N)			**	*	**	**	**
Urea: broadcast vs. band (1.0 × N)			**	**	**	**	**
Urea: side band vs. side band +P (1.0 × N)			**	0.09	0.10	0.20	0.20

Table 80. Nonrenewable energy input, energy output and energy use efficiency of flax at Star City 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	----------------	----------------	MJ ha^{-1})	----------------			
Treatment							
Urea side band, 0.5 × N	4220	1186	6250	17485	11235	2.8	118
Urea side band, 1.0 × N	7245	1226	9325	21849	12524	2.3	97
Urea side band, 1.5 × N	10270	1228	12352	22046	9694	1.8	74
Urea mid-row band, 0.5 × N	4220	1139	6208	21754	15546	3.5	145
Urea mid-row band, 1.0 × N	7245	1133	9226	21108	11883	2.3	95
Urea mid-row band, 1.5 × N	10270	1100	12210	17514	5304	1.4	60
Urea fall band, 1.0 × N	7245	1414	9562	15735	6173	1.6	70
Urea spring broadcast, 1.0 × N	7245	1249	9353	24384	15031	2.6	107
NH_3 side band, 0.5 × N	3283	1154	5289	21404	16115	4.1	168
NH_3 side band, 1.0 × N	5371	1161	7386	22140	14754	3.0	124
NH_3 side band, 1.5 × N	7460	1118	9421	17428	8007	1.9	78
NH_3 mid-row band, 0.5 × N	3283	1150	5284	20982	15698	4.0	165
NH_3 mid-row band, 1.0 × N	5371	1154	7378	21400	14022	2.9	120
NH_3 mid -row band, 1.5 × N	7460	1159	9472	21907	12435	2.3	96
NH_3 fall band, 1.0 × N	5371	1444	7725	14633	6908	1.9	81
Side band, no N	1194	1095	3129	16968	13840	5.4	229
Urea side band, 1.0 × N, seed-placed P	7245	1130	9221	20713	11492	2.3	93
Mean	6117	1191	1743	19968	11804	2.7	113
LSD (0.05)			59	5278	5218	0.7	27
Significance							
Treatment			**	*	**	**	**
Spring band: Urea vs. NH_3			**	0.59	*	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.68	0.78	0.48	0.41
Spring band: Side band vs. mid-row band			**	0.72	0.69	0.49	0.49
No vs. all other treatments			**	0.10	0.26	**	**
Spring band: 0 vs. 0.5 × N			**	0.10	0.70	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.36	0.30	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.15	**	**	**
Fall band vs. spring band (1.0 × N)			**	**	**	**	**
Urea: broadcast vs. band (1.0 × N)			0.47	*	*	0.08	0.07
Urea: side band vs. side band +P (1.0 × N)			**	0.67	0.69	0.79	0.79

Table 81. Nonrenewable energy input, energy output and energy use efficiency of wheat at Star City 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	---------------	---------------	MJ ha^{-1})	---------------			
Treatment							
Urea side band, 0.5 × N	4220	1053	5770	4119	-1651	0.7	61
Urea side band, 1.0 × N	7245	1052	8794	4005	-4789	0.5	40
Urea side band, 1.5 × N	10270	1057	11827	4878	-6949	0.4	33
Urea mid-row band, 0.5 × N	4220	949	5657	1333	-4324	0.2	36
Urea mid-row band, 1.0 × N	7245	955	8689	2220	-6469	0.3	29
Urea mid-row band, 1.5 × N	10270	965	11728	3884	-7844	0.3	29
Urea fall band, 1.0 × N	7245	1296	9101	4149	-4952	0.5	39
Urea spring broadcast, 1.0 × N	7245	1029	8765	353	-8412	0.0	17
NH_3 side band, 0.5 × N	3283	968	4743	1445	-3298	0.3	45
NH_3 side band, 1.0 × N	5371	974	6840	2490	-4350	0.4	39
NH_3 side band, 1.5 × N	7460	975	8929	2635	-6294	0.3	31
NH_3 mid-row band, 0.5 × N	3283	972	4748	2029	-2718	0.4	51
NH_3 mid-row band, 1.0 × N	5371	970	6834	1758	-5076	0.3	33
NH_3 mid -row band, 1.5 × N	7460	974	8928	2421	-6507	0.3	29
NH_3 fall band, 1.0 × N	5371	1321	7257	1737	-5520	0.2	31
Side band, no N	1194	950	2633	1502	-1131	0.6	81
Urea side band, 1.0 × N, seed-placed P	7245	955	8689	2256	-6433	0.3	29
Mean	6117	1024	7643	2542	-5101	0.3	38
LSD (0.05)			24	2922	2898	0.4	22
Significance							
Treatment			**	0.15	**	0.38	**
Spring band: Urea vs. NH_3			**	*	0.29	0.34	0.99
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.10	0.70	0.30	0.48
Spring band: Side band vs. mid-row band			**	0.10	0.12	0.13	0.14
No vs. all other treatments			**	0.30	**	0.12	**
Spring band: 0 vs. 0.5 × N			**	0.53	0.11	0.36	**
Spring band: 0.5 × vs. 1.0 × N			**	0.60	**	0.40	*
Spring band: 1.0 × vs. 1.5 × N			**	0.26	*	0.96	0.41
Fall band vs. spring band (1.0 × N)			**	0.72	0.94	0.90	0.99
Urea: broadcast vs. band (1.0 × N)			**	*	*	*	*
Urea: side band vs. side band +P (1.0 × N)			**	0.23	0.26	0.35	0.35

Table 82. *Annual and 3-year mean energy performance factors (mean of all treatments) and seed yields for three crops and three years at Star City.*

Energy factor determined	**2000**	**2001**	**2002**	**Mean**
Canola				
Seed Yield (Mg ha^{-1})	2.48	0.72	1.50	1.57
Gross energy output (MJ ha^{-1})	68596	19863	44034	44164
Net energy output (MJ ha^{-1})	60080	12287	36230	36199
Grain/unit of input energy (kg GJ^{-1})	296	97	201	198
Output/input ratio	8.7	2.8	5.9	5.8
Flax				
Seed Yield (Mg ha^{-1})	1.92	1.18	0.83	1.31
Gross energy output (MJ ha^{-1})	45357	27322	20713	31131
Net energy output (MJ ha^{-1})	36640	19304	11492	22479
Grain/unit of input energy (kg GJ^{-1})	227	158	113	166
Output/input ratio	5.7	3.9	2.3	4.0
Wheat				
Seed Yield (Mg ha^{-1})	2.28	0.99	0.27	1.18
Gross energy output (MJ ha^{-1})	37182	14903	2542	18209
Net energy output (MJ ha^{-1})	28660	7061	-5101	10207
Grain/unit of input energy (kg GJ^{-1})	260	131	38	143
Output/input ratio	4.5	2.1	0.3	2.3

Table 83. Non-renewable energy input, energy output, and energy use efficiency of canola at the Swift Current site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	----------	----------	(MJ ha^{-1})	----------	----------		(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1374	5246	46080	40834	8.8	299
Urea side band, 1.0 × N	5371	1388	7532	48074	40542	6.4	217
Urea side band, 1.5 × N	7640	1425	9847	53379	43532	5.4	184
Urea mid-row band, 0.5 × N	3102	1285	5152	45705	40553	8.9	302
Urea mid-row band, 1.0 × N	5371	1360	7514	56484	48970	7.5	256
Urea mid-row band, 1.5 × N	7640	1350	9769	54916	45147	5.6	191
Urea fall band, 1.0 × N	5371	1633	7840	48265	40425	6.1	210
Urea spring broadcast, 1.0 × N	5371	1365	7504	44756	37252	6.0	203
NH_3 side band, 0.5 × N	2399	1338	4515	50686	46171	11.2	382
NH_3 side band, 1.0 × N	3965	1339	6082	50759	44678	8.3	284
NH_3 side band, 1.5 × N	5532	1354	7667	52967	45300	6.9	235
NH_3 mid-row band, 0.5 × N	2399	1305	4473	45889	41415	10.2	349
NH_3 mid-row band, 1.0 × N	3965	1351	6097	52547	46450	8.6	293
NH_3 mid -row band, 1.5 × N	5532	1413	7741	61494	53753	7.9	269
NH_3 fall band, 1.0 × N	3965	1679	6490	49075	42584	7.6	258
Side band, no N	833	1187	2761	31505	28744	11.4	388
Urea side band, 1.0 × N, seed-placed P	5371	1300	7439	47809	40370	6.4	219
Mean	4525	1379	6686	49435	42748	7.8	267
LSD (0.05)			124	14330	14206	2.0	69
Significance							
Treatment			**	0.10	0.35	**	**
Spring band: Urea vs. NH_3			**	0.58	0.30	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.91	0.76	0.17	0.17
Spring band: Side band vs. mid-row band			0.35	0.39	0.38	0.49	0.49
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	*	0.05	0.05
Spring band: 0.5 × vs. 1.0 × N			**	0.18	0.41	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.30	0.62	*	*
Fall band vs. spring band (1.0 × N)			**	0.45	0.40	0.17	0.17
Urea: broadcast vs. band (1.0 × N)			*	0.29	0.30	0.39	0.39
Urea: side band vs. side band +P (1.0 × N)			0.14	0.97	0.98	0.97	0.97

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 84. Non-renewable energy input, energy output, and energy use efficiency of flax at the Swift Current site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	-------------	-------------	(MJ ha^{-1})	-------------	-------------		(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1467	5643	43685	38043	7.7	308
Urea side band, 1.0 × N	5371	1442	7881	40990	33109	5.2	208
Urea side band, 1.5 × N	7640	1506	10229	47953	37724	4.7	187
Urea mid-row band, 0.5 × N	3102	1405	5582	46329	40747	8.3	330
Urea mid-row band, 1.0 × N	5371	1359	7794	41334	33540	5.3	212
Urea mid-row band, 1.5 × N	7640	1432	10152	49258	39106	4.8	193
Urea fall band, 1.0 × N	5371	1675	8174	39847	31672	4.9	195
Urea spring broadcast, 1.0 × N	5371	1520	7977	49511	41534	6.2	247
NH_3 side band, 0.5 × N	2399	1430	4910	47056	42147	9.6	382
NH_3 side band, 1.0 × N	3965	1436	6483	47712	41229	7.4	293
NH_3 side band, 1.5 × N	5532	1418	8028	45764	37736	5.7	227
NH_3 mid-row band, 0.5 × N	2399	1367	4833	40237	35404	8.3	332
NH_3 mid-row band, 1.0 × N	3965	1465	6519	50875	44357	7.8	310
NH_3 mid -row band, 1.5 × N	5532	1369	7967	40386	32419	5.0	202
NH_3 fall band, 1.0 × N	3965	1753	6864	43945	37081	6.4	254
Side band, no N	833	1383	3286	43958	40672	13.3	533
Urea side band, 1.0 × N, seed-placed P	5371	1418	7866	47725	39859	6.1	241
Mean	4525	1461	7070	45092	38022	6.9	274
LSD (0.05)			119	10566	10447	1.4	55
Significance							
Treatment			**	0.54	0.44	**	**
Spring band: Urea vs. NH_3			**	0.85	0.39	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.44	0.30	*	*
Spring band: Side band vs. mid-row band			*	0.71	0.73	0.70	0.71
No vs. all other treatments			**	0.75	0.46	**	**
Spring band: 0 vs. 0.5 × N			**	0.93	0.70	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.73	0.69	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.82	0.62	**	**
Fall band vs. spring band (1.0 × N)			**	0.31	0.25	0.08	0.07
Urea: broadcast vs. band (1.0 × N)			0.58	*	*	0.07	0.07
Urea: side band vs. side band +P (1.0 × N)			0.80	0.21	0.20	0.23	0.23

*, ** Significant at $P<0.05$ and $P<0.01$ probability levels, respectively. Other probabilities given.

Table 85. Non-renewable energy input, energy output and energy use efficiency of wheat at the Swift Current site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	(MJ ha^{-1})						(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1367	5294	65452	60158	12.3	675
Urea side band, 1.0 × N	5371	1446	7666	78063	70397	10.2	556
Urea side band, 1.5 × N	7640	1339	9795	60901	51106	6.2	339
Urea mid-row band, 0.5 × N	3102	1282	5204	65504	60300	12.6	688
Urea mid-row band, 1.0 × N	5371	1313	7514	70537	63023	9.4	514
Urea mid-row band, 1.5 × N	7640	1313	9782	70499	60717	7.2	393
Urea fall band, 1.0 × N	5371	1641	7908	70228	62320	8.9	486
Urea spring broadcast, 1.0 × N	5371	1373	7570	66350	58780	8.7	478
NH_3 side band, 0.5 × N	2399	1311	4538	67253	62716	15.8	811
NH_3 side band, 1.0 × N	3965	1273	6054	61149	55095	10.0	554
NH_3 side band, 1.5 × N	5532	1339	7708	71842	64134	9.3	510
NH_3 mid-row band, 0.5 × N	2399	1268	4482	60447	55965	13.4	736
NH_3 mid-row band, 1.0 × N	3965	1252	6027	57851	51824	19.5	525
NH_3 mid -row band, 1.5 × N	5532	1391	7775	80083	72309	10.3	561
NH_3 fall band, 1.0 × N	3965	1708	6587	74513	67926	11.3	617
Side band, no N	833	1322	2987	71935	68948	23.9	1308
Urea side band, 1.0 × N, seed-placed P	5371	1327	7531	72712	65180	9.6	527
Mean	4525	1368	6731	68548	61818	11.3	604
LSD (0.05)			168	20609	20441	3.2	174
Significance							
Treatment			**	0.73	0.75	**	**
Spring band: Urea vs. NH_3			**	0.63	0.88	*	*
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.68	0.58	0.15	0.16
Spring band: Side band vs. mid-row band			0.19	0.99	0.98	0.89	0.90
No vs. all other treatments			**	0.63	0.31	**	**
Spring band: 0 vs. 0.5 × N			**	0.37	0.26	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.66	0.95	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.45	0.70	0.06	0.05
Fall band vs. spring band (1.0 × N)			**	0.39	0.42	0.78	0.79
Urea: broadcast vs. band (1.0 × N)			0.07	0.43	0.44	0.57	0.57
Urea: side band vs. side band +P (1.0 × N)			0.11	0.60	0.61	0.74	0.74

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 86. Non-renewable energy input, energy output, and energy use efficiency of canola at the Swift Current site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	-----	-----	(MJ ha^{-1})	-----			(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1127	4594	22411	17817	4.9	167
Urea side band, 1.0 × N	5371	1075	6798	14840	8042	2.2	75
Urea side band, 1.5 × N	7640	1098	9096	18247	9151	2.0	69
Urea mid-row band, 0.5 × N	3102	974	4419	12670	8250	2.9	99
Urea mid-row band, 1.0 × N	5371	1023	6749	19748	12998	2.9	100
Urea mid-row band, 1.5 × N	7640	1047	9048	23235	14187	2.6	88
Urea fall band, 1.0 × N	5371	1343	7135	18453	11318	2.6	89
Urea spring broadcast, 1.0 × N	5371	1120	6854	21410	14556	3.1	107
NH_3 side band, 0.5 × N	2399	1014	3767	15900	12133	4.2	144
NH_3 side band, 1.0 × N	3965	1060	5390	22536	17146	4.2	142
NH_3 side band, 1.5 × N	5532	1099	7005	28106	21101	4.0	137
NH_3 mid-row band, 0.5 × N	2399	1014	3767	15907	12140	4.2	145
NH_3 mid-row band, 1.0 × N	3965	1075	5408	24589	19181	4.5	156
NH_3 mid -row band, 1.5 × N	5532	1116	7026	30556	23530	4.3	148
NH_3 fall band, 1.0 × N	3965	1416	5819	23154	17335	4.0	136
Side band, no N	833	971	2146	12221	10074	5.7	195
Urea side band, 1.0 × N, seed-placed P	5371	1056	6790	24449	17659	3.6	123
Mean	4525	1096	5989	20496	14507	3.6	125
LSD (0.05)			69	7958	7889	1.5	51
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	**	**	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			0.24	0.13	0.07	0.07	0.07
Spring band: Side band vs. mid-row band			0.63	0.61	0.98	0.98	0.98
No vs. all other treatments			**	0.11	**	**	**
Spring band: 0 vs. 0.5 × N			0.16	0.42	**	**	**
Spring band: 0.5 × vs. 1.0 × N			0.07	0.38	0.12	0.12	0.12
Spring band: 1.0 × vs. 1.5 × N			*	0.18	0.54	0.55	0.54
Fall band vs. spring band (1.0 × N)			0.88	0.99	0.70	0.71	0.70
Urea: broadcast vs. band (1.0 × N)			0.25	0.25	0.37	0.37	0.37
Urea: side band vs. side band +P (1.0 × N)			*	*	0.06	0.06	0.06

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 87. Non-renewable energy input, energy output, and energy use efficiency of flax at the Swift Current site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	----------------	----------------	(MJ ha^{-1})	----------------			(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1115	4864	14231	9367	2.9	126
Urea side band, 1.0 × N	5371	1138	7160	16712	9551	2.3	99
Urea side band, 1.5 × N	7640	1098	9381	12392	3012	1.3	58
Urea mid-row band, 0.5 × N	3102	1047	4795	16173	11378	3.4	143
Urea mid-row band, 1.0 × N	5371	1108	7138	22817	15679	3.2	132
Urea mid-row band, 1.5 × N	7640	1022	9302	13464	4162	1.4	62
Urea fall band, 1.0 × N	5371	1341	7416	12276	4859	1.7	72
Urea spring broadcast, 1.0 × N	5371	1098	7111	12289	5178	1.7	75
NH_3 side band, 0.5 × N	2399	1107	4166	20732	16566	5.0	207
NH_3 side band, 1.0 × N	3965	1071	5688	16796	11108	2.9	124
NH_3 side band, 1.5 × N	5532	1030	7203	12289	5085	1.7	74
NH_3 mid-row band, 0.5 × N	2399	1090	4145	18861	14717	4.5	190
NH_3 mid-row band, 1.0 × N	3965	1053	5666	14887	9220	2.6	112
NH_3 mid -row band, 1.5 × N	5532	1068	7251	16491	9240	2.3	96
NH_3 fall band, 1.0 × N	3965	1409	6094	15315	9221	2.5	107
Side band, no N	833	1026	2500	13899	11399	5.5	239
Urea side band, 1.0 × N, seed-placed P	5371	1031	7044	14406	7362	2.0	88
Mean	4525	1108	6290	15531	9241	2.8	118
LSD (0.05)			56	5020	4964	0.9	35
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	0.49	*	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.23	0.08	*	*
Spring band: Side band vs. mid-row band			*	0.13	0.12	0.26	0.25
No vs. all other treatments			**	0.35	0.21	**	**
Spring band: 0 vs. 0.5 × N			**	0.07	0.41	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.81	0.20	**	**
Spring band: 1.0 × vs. 1.5 × N			**	**	**	**	**
Fall band vs. spring band (1.0 × N)			**	**	**	*	*
Urea: broadcast vs. band (1.0 × N)			**	*	*	0.07	0.07
Urea: side band vs. side band +P (1.0 × N)			**	0.36	0.38	0.52	0.53

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 88. Non-renewable energy input, energy output, and energy use efficiency of wheat at the Swift Current site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	-----------------------	-----------------------	(MJ ha^{-1})	-----------------------			(kg GJ^{-1})
Urea side band, 0.5 × N	3102	944	4399	10688	6289	2.4	150
Urea side band, 1.0 × N	5371	948	6674	11451	4776	1.7	105
Urea side band, 1.5 × N	7640	942	8935	10468	1533	1.2	73
Urea mid-row band, 0.5 × N	3102	861	4313	11273	6960	2.6	161
Urea mid-row band, 1.0 × N	5371	866	6587	11932	5345	1.8	110
Urea mid-row band, 1.5 × N	7640	845	8829	8649	-181	1.0	63
Urea fall band, 1.0 × N	5371	1185	6971	10361	3389	1.5	92
Urea spring broadcast, 1.0 × N	5371	939	6662	9949	3287	1.5	93
NH_3 side band, 0.5 × N	2399	863	3612	8667	5056	2.4	153
NH_3 side band, 1.0 × N	3965	866	5181	9046	3865	1.7	111
NH_3 side band, 1.5 × N	5532	868	6750	9402	2652	1.4	88
NH_3 mid-row band, 0.5 × N	2399	884	3638	11928	8290	3.3	200
NH_3 mid-row band, 1.0 × N	3965	876	5195	10768	5573	2.1	128
NH_3 mid -row band, 1.5 × N	5532	875	6759	10515	3756	1.6	96
NH_3 fall band, 1.0 × N	3965	1224	5614	10192	4579	1.8	113
Side band, no N	833	863	2046	11516	9470	5.6	344
Urea side band, 1.0 × N, seed-placed P	5371	848	6564	9060	2496	1.4	87
Mean	4525	923	5808	10345	4537	2.1	128
LSD (0.05)			23	2758	2736	0.6	31
Significance							
Treatment			**	0.26	**	**	**
Spring band: Urea vs. NH_3			**	0.22	0.19	*	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.90	0.39	.027	0.19
Spring band: Side band vs. mid-row band			**	0.12	0.10	*	*
No vs. all other treatments			**	0.22	**	**	**
Spring band: 0 vs. 0.5 × N			**	0.42	*	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.82	*	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.14	**	**	**
Fall band vs. spring band (1.0 × N)			**	0.54	0.28	0.31	0.26
Urea: broadcast vs. band (1.0 × N)			**	0.25	0.28	0.46	0.47
Urea: side band vs. side band +P (1.0 × N)			**	0.09	0.10	0.26	0.26

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 89. Nonrenewable energy input, energy output and energy use efficiency of canola at Swift Current 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	-----------------MJ ha^{-1})-----------------						
Treatment							
Urea side band, 0.5 × N	3102	1241	4736	32870	28134	6.9	236
Urea side band, 1.0 × N	5371	1324	7108	44782	37674	6.3	215
Urea side band, 1.5 × N	7640	1156	9169	20660	11491	2.2	77
Urea mid-row band, 0.5 × N	3102	1110	4590	26419	21830	5.7	196
Urea mid-row band, 1.0 × N	5371	1180	6945	36453	29507	5.2	179
Urea mid-row band, 1.5 × N	7640	1192	9229	38210	28981	4.1	141
Urea fall band, 1.0 × N	5371	1497	7327	34661	27334	4.7	162
Urea spring broadcast, 1.0 × N	5371	1223	6983	30252	23269	4.3	148
NH_3 side band, 0.5 × N	2399	1179	3972	33677	29705	8.5	289
NH_3 side band, 1.0 × N	3965	1188	5550	34986	29436	6.3	215
NH_3 side band, 1.5 × N	5532	1175	7100	33129	26029	4.7	159
NH_3 mid-row band, 0.5 × N	2399	1118	3897	24976	21079	6.4	218
NH_3 mid-row band, 1.0 × N	3965	1183	5544	34313	28769	6.2	211
NH_3 mid -row band, 1.5 × N	5532	1251	7195	44093	36899	6.1	209
NH_3 fall band, 1.0 × N	3965	1515	5942	31424	25481	5.3	181
Side band, no N	833	1055	2252	18463	16211	8.2	280
Urea side band, 1.0 × N, seed-placed P	5371	1193	6961	38278	31317	5.5	188
Mean	4525	1222	6147	32803	26656	5.7	194
LSD (0.05)			92	10611	10520	1.9	65
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	0.66	0.27	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.54	0.72	0.56	0.56
Spring band: Side band vs. mid-row band			*	0.74	0.72	0.65	0.65
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	*	*	*	0.08
Spring band: 0.5 × vs. 1.0 × N			**	**	*	*	0.07
Spring band: 1.0 × vs. 1.5 × N			**	0.18	*	**	**
Fall band vs. spring band (1.0 × N)			**	0.16	0.13	*	*
Urea: broadcast vs. band (1.0 × N)			**	0.06	0.06	0.17	0.17
Urea: side band vs. side band +P (1.0 × N)			**	0.22	0.23	0.41	0.41

Table 90. Nonrenewable energy input, energy output and energy use efficiency of flax at Swift Current 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	--------------------	--------------------	MJ ha^{-1})	--------------------			
Treatment							
Urea side band, 0.5 × N	3102	1284	5073	28186	23113	5.6	226
Urea side band, 1.0 × N	5371	1341	7412	34451	27039	4.6	187
Urea side band, 1.5 × N	7640	1315	9649	31579	21930	3.3	132
Urea mid-row band, 0.5 × N	3102	1217	5005	30253	25248	6.0	245
Urea mid-row band, 1.0 × N	5371	1239	7301	32673	25371	4.5	181
Urea mid-row band, 1.5 × N	7640	1218	9545	30421	20876	3.2	129
Urea fall band, 1.0 × N	5371	1556	7682	31266	23584	4.1	165
Urea spring broadcast, 1.0 × N	5371	1287	7345	28530	21185	3.9	158
NH_3 side band, 0.5 × N	2399	1230	4319	29701	25382	6.9	279
NH_3 side band, 1.0 × N	3965	1218	5870	28390	22520	4.8	196
NH_3 side band, 1.5 × N	5532	1212	7429	27718	20289	3.7	152
NH_3 mid-row band, 0.5 × N	2399	1189	4269	25267	20998	5.9	243
NH_3 mid-row band, 1.0 × N	3965	1251	5911	32019	26108	5.4	219
NH_3 mid -row band, 1.5 × N	5532	1249	7475	31805	24331	4.3	172
NH_3 fall band, 1.0 × N	3965	1547	6266	25934	19668	4.1	169
Side band, no N	833	1099	2591	17329	14738	6.7	281
Urea side band, 1.0 × N, seed-placed P	5371	1170	7217	25170	17953	3.5	142
Mean	4525	1272	6492	28864	22372	4.7	193
LSD (0.05)			78	6941	6863	1.1	41
Significance							
Treatment			**	**	0.07	**	**
Spring band: Urea vs. NH_3			**	0.14	0.64	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.13	0.26	0.90	0.83
Spring band: Side band vs. mid-row band			*	0.78	0.75	0.75	0.75
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	0.18	*
Spring band: 0.5 × vs. 1.0 × N			**	*	0.36	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.39	*	**	**
Fall band vs. spring band (1.0 × N)			**	0.13	0.09	*	*
Urea: broadcast vs. band (1.0 × N)			**	0.14	0.14	0.25	0.25
Urea: side band vs. side band +P (1.0 × N)			**	**	**	*	0.03

Table 91. Nonrenewable energy input, energy output and energy use efficiency of wheat at Swift Current 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	MJ ha^{-1}						
Treatment							
Urea side band, 0.5 × N	3102	1055	4543	21982	17438	4.8	278
Urea side band, 1.0 × N	5371	1115	6890	31550	24660	4.6	257
Urea side band, 1.5 × N	7640	1116	9161	31798	22637	3.5	195
Urea mid-row band, 0.5 × N	3102	966	4448	21394	16946	4.8	277
Urea mid-row band, 1.0 × N	5371	1016	6783	29504	22721	4.3	245
Urea mid-row band, 1.5 × N	7640	1019	9055	29909	20853	3.3	186
Urea fall band, 1.0 × N	5371	1295	7114	21480	14366	3.0	174
Urea spring broadcast, 1.0 × N	5371	1039	6791	19429	12637	2.9	166
NH_3 side band, 0.5 × N	2399	991	3777	22509	18732	6.0	342
NH_3 side band, 1.0 × N	3965	1064	5439	34293	28854	6.3	353
NH_3 side band, 1.5 × N	5532	1047	6983	31569	24586	4.5	254
NH_3 mid-row band, 0.5 × N	2399	951	3725	16238	12512	4.3	256
NH_3 mid-row band, 1.0 × N	3965	1016	5377	26643	21266	5.0	282
NH_3 mid -row band, 1.5 × N	5532	1008	6933	25374	18442	3.7	208
NH_3 fall band, 1.0 × N	3965	1367	5799	26521	20722	4.5	258
Side band, no N	833	913	2111	13023	10913	6.2	372
Urea side band, 1.0 × N, seed-placed P	5371	1013	6778	28931	22153	4.3	241
Mean	4525	1058	5983	25420	19438	4.5	256
LSD (0.05)			58	7078	7021	1.2	63
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	0.28	0.92	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.16	0.08	**	**
Spring band: Side band vs. mid-row band			**	**	**	**	**
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	*	**	**
Spring band: 0.5 × vs. 1.0 × N			**	**	**	0.85	0.80
Spring band: 1.0 × vs. 1.5 × N			**	0.64	0.12	**	**
Fall band vs. spring band (1.0 × N)			**	**	**	**	**
Urea: broadcast vs. band (1.0 × N)			**	**	**	*	*
Urea: side band vs. side band +P (1.0 × N)			**	0.46	0.48	0.61	0.61

Table 92. Annual and 3-year mean energy performance factors (mean of all treatments) and seed yields for three crops and three years at Swift Current.

Energy factor determined	2000	2001	2002	Mean
Canola				
Seed Yield (Mg ha^{-1})	1.68	0.69	1.12	1.16
Gross energy output (MJ ha^{-1})	49435	20496	32803	34245
Net energy output (MJ ha^{-1})	42748	14507	26656	27970
Grain/unit of input energy (kg GJ^{-1})	267	125	194	195
Output/input ratio	7.8	3.6	5.7	5.7
Flax				
Seed Yield (Mg ha^{-1})	1.80	0.66	1.17	1.21
Gross energy output (MJ ha^{-1})	45092	15531	28864	29829
Net energy output (MJ ha^{-1})	38022	9241	22372	23211
Grain/unit of input energy (kg GJ^{-1})	274	118	193	195
Output/input ratio	6.9	2.8	4.7	4.8
Wheat				
Seed Yield (Mg ha^{-1})	3.71	0.71	1.45	1.96
Gross energy output (MJ ha^{-1})	68548	10345	25420	34771
Net energy output (MJ ha^{-1})	61818	4537	19438	28598
Grain/unit of input energy (kg GJ^{-1})	604	128	256	329
Output/input ratio	11.3	2.1	4.5	6.0

Table 93. Non-renewable energy input, energy output, and energy use efficiency of canola at the Scott site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
			(MJ ha^{-1})				(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1299	5164	35264	30100	6.8	232
Urea side band, 1.0 × N	5371	1308	7445	36633	29188	4.9	168
Urea side band, 1.5 × N	7640	1364	9783	44653	34870	4.6	156
Urea mid-row band, 0.5 × N	3102	1192	5047	32211	27164	6.4	218
Urea mid-row band, 1.0 × N	5371	1221	7353	36501	29147	5.0	169
Urea mid-row band, 1.5 × N	7640	1252	9660	40849	31189	4.2	144
Urea fall band, 1.0 × N	5371	1563	7765	38230	30465	4.9	168
Urea spring broadcast, 1.0 × N	5371	1287	7419	33594	26175	4.5	155
NH_3 side band, 0.5 × N	2399	1171	4319	26656	22337	6.2	211
NH_3 side band, 1.0 × N	3965	1191	5910	29482	23572	5.0	171
NH_3 side band, 1.5 × N	5532	1278	7584	41989	34405	5.5	189
NH_3 mid-row band, 0.5 × N	2399	1150	4293	23610	19318	5.5	188
NH_3 mid-row band, 1.0 × N	3965	1159	5871	24979	19108	4.2	145
NH_3 mid -row band, 1.5 × N	5532	1210	7500	32226	24726	4.3	147
NH_3 fall band, 1.0 × N	3965	1546	6338	30041	23703	4.7	162
Side band, no N	833	1093	2656	18063	15406	6.8	232
Urea side band, 1.0 × N, seed-placed P	5371	1230	7363	37663	30300	5.1	175
Mean	4525	992	1526	33096	26540	5.2	178
LSD (0.05)			56	6438	6382	1.2	41
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	**	**	0.43	0.45
Fall band: Urea vs. NH_3 (1.0 × N)			**	*	*	0.75	0.75
Spring band: Side band vs. mid-row band			**	**	**	*	*
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	0.23	0.21
Spring band: 0.5 × vs. 1.0 × N			**	0.13	0.74	**	**
Spring band: 1.0 × vs. 1.5 × N			**	**	**	0.67	0.65
Fall band vs. spring band (1.0 × N)			**	0.26	0.35	0.89	0.90
Urea: broadcast vs. band (1.0 × N)			**	0.18	0.19	0.39	0.40
Urea: side band vs. side band +P (1.0 × N)			**	0.75	0.73	0.74	0.74

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 94. Non-renewable energy input, energy output and energy use efficiency of flax at the Scott site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	(MJ ha^{-1})						(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1477	5450	44841	39392	8.2	328
Urea side band, 1.0 × N	5371	1553	7812	53142	45330	6.8	270
Urea side band, 1.5 × N	7640	1579	10113	55954	45842	5.5	219
Urea mid-row band, 0.5 × N	3102	1345	5302	39756	34454	7.5	300
Urea mid-row band, 1.0 × N	5371	1445	7694	50732	43038	6.6	262
Urea mid-row band, 1.5 × N	7640	1486	10013	55156	45143	5.5	218
Urea fall band, 1.0 × N	5371	1754	8065	48440	40375	6.0	239
Urea spring broadcast, 1.0 × N	5371	1466	7704	43568	35864	5.7	226
NH_3 side band, 0.5 × N	2399	1361	4619	39561	34942	8.6	343
NH_3 side band, 1.0 × N	3965	1458	6305	50187	43882	8.0	316
NH_3 side band, 1.5 × N	5532	1496	7917	54272	46355	6.9	272
NH_3 mid-row band, 0.5 × N	2399	1343	4597	37580	32983	8.2	328
NH_3 mid-row band, 1.0 × N	3965	1416	6252	45510	39258	7.3	290
NH_3 mid -row band, 1.5 × N	5532	1440	7848	48134	40286	6.1	244
NH_3 fall band, 1.0 × N	3965	1734	6636	41925	35290	6.3	253
Side band, no N	833	1229	2890	27032	24142	9.3	382
Urea side band, 1.0 × N, seed-placed P	5371	1453	7703	51525	43822	6.7	266
Mean	4525	806	1218	46313	39435	7.0	280
LSD (0.05)			50	4413	4363	0.6	24
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	**	**	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	**	*	0.31	0.25
Spring band: Side band vs. mid-row band			**	**	**	**	**
No vs. all other treatments			**	**	**	**	**
Spring band: 0 vs. 0.5 × N			**	**	**	**	**
Spring band: 0.5 × vs. 1.0 × N			**	**	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	**	0.17	**	**
Fall band vs. spring band (1.0 × N)			**	**	**	**	**
Urea: broadcast vs. band (1.0 × N)			**	**	**	**	**
Urea: side band vs. side band +P (1.0 × N)			**	0.46	0.49	0.71	0.72

*, ** Significant at *P<0.05* and *P<0.01* probability levels, respectively. Other probabilities given.

Table 95. Non-renewable energy input, energy output, and energy use efficiency of wheat at the Scott site in 2000

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	---------------	---------------	(MJ ha^{-1})	---------------			(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1142	5057	28453	23397	5.6	327
Urea side band, 1.0 × N	5371	1201	7404	38005	30601	5.1	292
Urea side band, 1.5 × N	7640	1273	9766	49460	39694	5.1	284
Urea mid-row band, 0.5 × N	3102	1040	4945	25871	20926	5.2	307
Urea mid-row band, 1.0 × N	5371	1131	7333	40442	33109	5.5	313
Urea mid-row band, 1.5 × N	7640	1146	9621	42855	33234	4.5	252
Urea fall band, 1.0 × N	5371	1469	7742	41957	34216	5.4	307
Urea spring broadcast, 1.0 × N	5371	1155	7343	30647	23304	4.2	241
NH_3 side band, 0.5 × N	2399	1038	4238	22681	18443	5.3	317
NH_3 side band, 1.0 × N	3965	1080	5860	29506	23645	5.0	292
NH_3 side band, 1.5 × N	5532	1184	7562	45092	38530	6.1	343
NH_3 mid-row band, 0.5 × N	2399	1014	4207	18841	14634	4.5	271
NH_3 mid-row band, 1.0 × N	3965	1070	5847	27878	22031	4.8	278
NH_3 mid -row band, 1.5 × N	5532	1098	7449	32293	24844	4.3	250
NH_3 fall band, 1.0 × N	3965	1441	6296	30965	24669	4.9	284
Side band, no N	833	952	2561	11853	9291	4.6	300
Urea side band, 1.0 × N, seed-placed P	5371	1136	7340	41330	33991	5.6	319
Mean	4525	1151	6504	32900	26386	5.0	293
LSD (0.05)			31	3775	3744	0.6	31
Significance							
Treatment			**	**	**	**	**
Spring band: Urea vs. NH_3			**	**	**	0.18	0.52
Fall band: Urea vs. NH_3 (1.0 × N)			**	**	**	0.09	0.15
Spring band: Side band vs. mid-row band			**	**	**	**	**
No vs. all other treatments			**	**	**	*	0.53
Spring band: 0 vs. 0.5 × N			**	**	**	*	0.63
Spring band: 0.5 × vs. 1.0 × N			**	**	**	0.69	0.13
Spring band: 1.0 × vs. 1.5 × N			**	**	**	0.39	0.15
Fall band vs. spring band (1.0 × N)			**	*	0.07	0.75	0.85
Urea: broadcast vs. band (1.0 × N)			**	**	**	**	**
Urea: side band vs. side band +P (1.0 × N)			**	0.08	0.08	0.09	0.09

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 96. Non-renewable energy input, energy output and energy use efficiency of canola at the Scott site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	(MJ ha^{-1})						(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1239	5271	20711	15440	3.9	135
Urea side band, 1.0 × N	5371	1242	7545	21204	13660	2.8	96
Urea side band, 1.5 × N	7640	1274	9853	25781	15928	2.6	90
Urea mid-row band, 0.5 × N	3102	1152	5180	20601	15421	4.0	136
Urea mid-row band, 1.0 × N	5371	1178	7481	24339	16858	3.2	111
Urea mid-row band, 1.5 × N	7640	1181	9754	24787	15034	2.5	87
Urea fall band, 1.0 × N	5371	1504	7874	23927	16053	3.0	104
Urea spring broadcast, 1.0 × N	5371	1263	7570	24162	16592	3.2	109
NH_3 side band, 0.5 × N	2399	1159	4486	19049	14563	4.2	146
NH_3 side band, 1.0 × N	3965	1164	6058	19703	13646	3.2	111
NH_3 side band, 1.5 × N	5532	1193	7660	23860	16200	3.1	106
NH_3 mid-row band, 0.5 × N	2399	1179	4510	21896	17385	4.9	166
NH_3 mid-row band, 1.0 × N	3965	1202	6105	25185	19080	4.1	141
NH_3 mid -row band, 1.5 × N	5532	1223	7698	28260	20562	3.7	125
NH_3 fall band, 1.0 × N	3965	1533	6503	22249	15746	3.4	117
Side band, no N	833	1148	2905	19976	17070	6.9	235
Urea side band, 1.0 × N, seed-placed P	5371	1190	7496	26053	18557	3.5	119
Mean	4525	936	6703	23044	16341	3.7	126
LSD (0.05)			54	6253	6199	1.0	35
Significance							
Treatment			**	0.18	0.77	**	**
Spring band: Urea vs. NH_3			**	0.94	0.23	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.59	0.92	0.46	0.46
Spring band: Side band vs. mid-row band			*	0.06	0.05	0.06	0.06
No vs. all other treatments			**	0.15	0.73	**	**
Spring band: 0 vs. 0.5 × N			**	0.81	0.58	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.20	0.94	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.05	0.47	0.15	0.15
Fall band vs. spring band (1.0 × N)			**	0.80	0.96	0.69	0.68
Urea: broadcast vs. band (1.0 × N)			**	0.69	0.67	0.70	0.70
Urea: side band vs. side band +P (1.0 × N)			0.07	0.13	0.12	0.20	0.20

*, ** Significant at $P<0.05$ and $P<0.01$ probability levels, respectively. Other probabilities given.

Table 97. Non-renewable energy input, energy output and energy use efficiency of flax at the Scott site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	$(\mathrm{MJ\ ha^{-1}})$						$(\mathrm{kg\ GJ^{-1}})$
Urea side band, 0.5 × N	3102	1293	4973	29215	24242	5.9	239
Urea side band, 1.0 × N	5371	1287	7235	28565	21330	3.9	161
Urea side band, 1.5 × N	7640	1292	9510	29117	19607	3.1	124
Urea mid-row band, 0.5 × N	3102	1252	4937	34105	29168	6.9	279
Urea mid-row band, 1.0 × N	5371	1186	7125	26863	19739	3.8	153
Urea mid-row band, 1.5 × N	7640	1255	9478	34398	24919	3.6	146
Urea fall band, 1.0 × N	5371	1558	7574	31566	23991	4.2	169
Urea spring broadcast, 1.0 × N	5371	1304	7255	30377	23122	4.2	170
NH_3 side band, 0.5 × N	2399	1204	4175	26824	22649	6.4	262
NH_3 side band, 1.0 × N	3965	1246	5793	31429	25636	5.4	219
NH_3 side band, 1.5 × N	5532	1245	7359	31364	24006	4.3	173
NH_3 mid-row band, 0.5 × N	2399	1233	4211	29987	25777	7.1	289
NH_3 mid-row band, 1.0 × N	3965	1246	5794	31481	25688	5.4	219
NH_3 mid -row band, 1.5 × N	5532	1262	7380	33235	25855	4.5	182
NH_3 fall band, 1.0 × N	3965	1564	6176	27825	21649	4.5	183
Side band, no N	833	1154	2548	23382	20834	9.2	377
Urea side band, 1.0 × N, seed-placed P	5371	1168	7102	24869	17767	3.5	143
Mean	4525	1279	6390	29683	23293	5.0	205
LSD (0.05)			103	9149	9046	1.4	55
Significance							
Treatment			**	0.56	0.66	**	**
Spring band: Urea vs. NH_3			**	0.85	0.34	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.42	0.60	0.65	0.60
Spring band: Side band vs. mid-row band			0.34	0.23	0.22	0.18	0.18
No vs. all other treatments			**	*	0.43	**	**
Spring band: 0 vs. 0.5 × N			**	0.07	0.20	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.84	0.30	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.29	0.83	*	*
Fall band vs. spring band (1.0 × N)			**	0.97	0.92	0.48	0.45
Urea: broadcast vs. band (1.0 × N)			0.19	0.71	0.70	0.70	0.69
Urea: side band vs. side band +P (1.0 × N)			*	0.42	0.43	0.53	0.53

*, ** Significant at *$P<0.05$* and *$P<0.01$* probability levels, respectively. Other probabilities given.

Table 98. Non-renewable energy input, energy output and energy use efficiency of wheat at the Scott site in 2001

Treatment	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input
	--------------------	--------------------	(MJ ha^{-1})	--------------------			(kg GJ^{-1})
Urea side band, 0.5 × N	3102	1100	5002	21816	16813	4.4	260
Urea side band, 1.0 × N	5371	1091	7259	20286	13027	2.8	168
Urea side band, 1.5 × N	7640	1072	9503	17293	7789	1.8	111
Urea mid-row band, 0.5 × N	3102	1021	4921	22938	18018	4.7	276
Urea mid-row band, 1.0 × N	5371	1007	7171	20684	13513	2.9	173
Urea mid-row band, 1.5 × N	7640	1019	9456	22574	13118	2.4	142
Urea fall band, 1.0 × N	5371	1327	7555	19089	11534	2.5	153
Urea spring broadcast, 1.0 × N	5371	1108	7282	23112	15830	3.2	188
NH_3 side band, 0.5 × N	2399	1023	4219	20296	16077	4.8	288
NH_3 side band, 1.0 × N	3965	1032	5797	21769	15972	3.8	224
NH_3 side band, 1.5 × N	5532	1010	7334	18186	10852	2.5	151
NH_3 mid-row band, 0.5 × N	2399	1056	4262	25563	21301	6.0	352
NH_3 mid-row band, 1.0 × N	3965	1032	5798	21821	16023	3.8	224
NH_3 mid-row band, 1.5 × N	5532	1063	7404	26718	19314	3.6	211
NH_3 fall band, 1.0 × N	3965	1394	6234	23402	17168	3.8	222
Side band, no N	833	999	2623	19360	16737	7.4	445
Urea side band, 1.0 × N, seed-placed P	5371	1017	7184	22227	15044	3.1	184
Mean	4525	1081	6412	21596	15184	3.7	222
LSD (0.05)			37	4508	4472	0.8	42
Significance							
Treatment			**	*	**	**	**
Spring band: Urea vs. NH_3			**	0.12	**	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.06	*	**	**
Spring band: Side band vs. mid-row band			*	**	**	**	**
No vs. all other treatments			**	0.15	0.31	**	**
Spring band: 0 vs. 0.5 × N			**	0.07	0.46	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.18	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.96	0.10	**	**
Fall band vs. spring band (1.0 × N)			**	0.94	0.84	0.51	0.45
Urea: broadcast vs. band (1.0 × N)			**	0.10	0.09	0.17	0.17
Urea: side band vs. side band +P (1.0 × N)			**	0.39	0.37	0.45	0.44

*, ** Significant at *P<0.05* and *P<0.01* probability levels, respectively. Other probabilities given.

Table 99. Nonrenewable energy input, energy output and energy use efficiency of canola at Scott 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	-------------------------	-------------------------	MJ ha^{-1})	-------------------------			
Treatment							
Urea side band, 0.5 × N	3102	1089	4749	5167	417	1.1	38
Urea side band, 1.0 × N	5371	1095	7025	5948	-1077	0.9	30
Urea side band, 1.5 × N	7640	1098	9298	6446	-2852	0.7	24
Urea mid-row band, 0.5 × N	3102	1030	4691	8912	4221	1.9	66
Urea mid-row band, 1.0 × N	5371	1028	6957	8663	1706	1.2	43
Urea mid-row band, 1.5 × N	7640	1021	9218	7667	-1550	0.8	29
Urea fall band, 1.0 × N	5371	1355	7351	8374	1022	1.1	39
Urea spring broadcast, 1.0 × N	5371	1106	7039	7557	519	1.1	37
NH_3 side band, 0.5 × N	2399	1047	4010	8860	4850	2.2	76
NH_3 side band, 1.0 × N	3965	1041	5569	8020	2452	1.4	50
NH_3 side band, 1.5 × N	5532	1066	7165	11528	4363	1.6	55
NH_3 mid-row band, 0.5 × N	2399	1049	4013	9190	5177	2.3	79
NH_3 mid-row band, 1.0 × N	3965	1036	5562	7279	1717	1.3	45
NH_3 mid -row band, 1.5 × N	5532	1033	7125	6799	-326	1.0	33
NH_3 fall band, 1.0 × N	3965	1391	5989	7685	1695	1.3	45
Side band, no N	833	1022	2412	7847	5434	3.3	113
Urea side band, 1.0 × N, seed-placed P	5371	1019	6947	7413	466	1.1	37
Mean	4525	1090	6183	7844	1661	1.4	49
LSD (0.05)			29	3320	3291	0.6	22
Significance							
Treatment			**	0.13	**	**	**
Spring band: Urea vs. NH_3			**	*	**	**	**
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.68	0.68	0.66	0.65
Spring band: Side band vs. mid-row band			**	0.53	0.49	0.42	0.42
No vs. all other treatments			**	0.99	**	**	**
Spring band: 0 vs. 0.5 × N			**	0.89	0.18	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.51	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	0.44	0.12	0.26	0.24
Fall band vs. spring band (1.0 × N)			**	0.59	0.87	0.99	0.99
Urea: broadcast vs. band (1.0 × N)			**	0.94	0.98	0.99	0.99
Urea: side band vs. side band +P (1.0 × N)			**	0.38	0.35	0.50	0.50

Table 100. Nonrenewable energy input, energy output and energy use efficiency of flax at Scott 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	-----------------	-----------------	-MJ ha^{-1})-	-----------------			
Treatment							
Urea side band, 0.5 × N	3102	1114	4782	5065	283	1.1	54
Urea side band, 1.0 × N	5371	1111	7048	4809	-2239	0.7	35
Urea side band, 1.5 × N	7640	1111	9316	4738	-4578	0.5	26
Urea mid-row band, 0.5 × N	3102	1033	4698	5683	985	1.2	60
Urea mid-row band, 1.0 × N	5371	1012	6941	3357	-3583	0.5	28
Urea mid-row band, 1.5 × N	7640	1029	9231	5239	-3992	0.6	29
Urea fall band, 1.0 × N	5371	1348	7345	4037	-3308	0.6	30
Urea spring broadcast, 1.0 × N	5371	1112	7049	4927	-2122	0.7	36
NH_3 side band, 0.5 × N	2399	1044	4009	4886	877	1.2	63
NH_3 side band, 1.0 × N	3965	1040	5571	4487	-1083	0.8	42
NH_3 side band, 1.5 × N	5532	1050	7149	5556	-1593	0.8	39
NH_3 mid-row band, 0.5 × N	2399	1040	4004	4457	453	1.1	59
NH_3 mid-row band, 1.0 × N	3965	1031	5560	3511	-2049	0.6	36
NH_3 mid -row band, 1.5 × N	5532	1046	7144	5157	-1988	0.7	37
NH_3 fall band, 1.0 × N	3965	1380	5980	3209	-2770	0.5	31
Side band, no N	833	1038	2435	6174	3739	2.5	123
Urea side band, 1.0 × N, seed-placed P	5371	1031	6964	5392	-1572	0.8	39
Mean	4525	1092	6190	4746	-1444	0.8	45
LSD (0.05)			20	1734	1714	0.4	14
Significance							
Treatment			**	*	**	**	**
Spring band: Urea vs. NH_3			**	0.69	**	0.10	*
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.34	0.53	0.94	0.83
Spring band: Side band vs. mid-row band			**	0.32	0.38	0.47	0.49
No vs. all other treatments			**	*	**	**	**
Spring band: 0 vs. 0.5 × N			**	0.10	**	**	**
Spring band: 0.5 × vs. 1.0 × N			**	*	**	**	**
Spring band: 1.0 × vs. 1.5 × N			**	**	0.07	0.94	0.45
Fall band vs. spring band (1.0 × N)			**	0.43	0.13	0.34	0.27
Urea: broadcast vs. band (1.0 × N)			**	0.23	0.19	0.40	0.39
Urea: side band vs. side band +P (1.0 × N)			**	0.50	0.44	0.61	0.60

Table 101. Nonrenewable energy input, energy output and energy use efficiency of wheat at Scott 2002

	Fertilizer	Fuel & Oil	Total Input	Gross Output	Net Output	Output/ Input Ratio	Grain/Unit of Input (kg GJ^{-1})
	MJ ha^{-1}						
Treatment							
Urea side band, 0.5 × N	3102	974	4617	1603	-3013	0.4	48
Urea side band, 1.0 × N	5371	971	6882	1095	-5787	0.2	28
Urea side band, 1.5 × N	7640	971	9150	1081	-8070	0.1	21
Urea mid-row band, 0.5 × N	3102	885	4521	1033	-3489	0.2	42
Urea mid-row band, 1.0 × N	5371	884	6790	999	-5791	0.2	28
Urea mid-row band, 1.5 × N	7640	882	9055	563	-8493	0.1	18
Urea fall band, 1.0 × N	5371	1214	7186	956	-6230	0.1	26
Urea spring broadcast, 1.0 × N	5371	962	6870	-368	-7238	-0.1	17
NH_3 side band, 0.5 × N	2399	906	3846	1570	-2276	0.4	57
NH_3 side band, 1.0 × N	3965	901	5405	779	-4627	0.1	32
NH_3 side band, 1.5 × N	5532	900	6970	635	-6336	0.1	24
NH_3 mid-row band, 0.5 × N	2399	900	3838	639	-3199	0.2	44
NH_3 mid-row band, 1.0 × N	3965	896	5398	-90	-5488	0.0	24
NH_3 mid -row band, 1.5 × N	5532	897	6967	150	-6816	0.0	20
NH_3 fall band, 1.0 × N	3965	1251	5827	534	-5293	0.1	28
Side band, no N	833	891	2261	2054	-207	0.9	108
Urea side band, 1.0 × N, seed-placed P	5371	886	6792	1253	-5539	0.2	30
Mean	4525	951	6022	852	-5170	0.2	35
LSD (0.05)			12	1478	1466	0.4	19
Significance							
Treatment			**	0.19	**	**	**
Spring band: Urea vs. NH_3			**	0.14	**	0.58	0.46
Fall band: Urea vs. NH_3 (1.0 × N)			**	0.57	0.20	0.82	0.82
Spring band: Side band vs. mid-row band			**	0.06	0.08	0.14	0.15
No vs. all other treatments			**	*	**	**	**
Spring band: 0 vs. 0.5 × N			**	0.15	**	**	**
Spring band: 0.5 × vs. 1.0 × N			**	0.17	**	*	**
Spring band: 1.0 × vs. 1.5 × N			**	0.81	**	0.70	0.14
Fall band vs. spring band (1.0 × N)			**	0.91	0.45	0.97	0.84
Urea: broadcast vs. band (1.0 × N)			**	*	*	0.18	0.18
Urea: side band vs. side band +P (1.0 × N)			**	0.83	0.74	0.89	0.86

Table 102. Annual and 3-year mean energy performance factors (mean of all treatments) and seed yields for three crops and three years at Scott.

Energy factor determined	2000	2001	Mean
Canola			
Seed Yield (Mg ha^{-1})	1.24	0.87	1.05
Gross energy output (MJ ha^{-1})	33096	23044	28070
Net energy output (MJ ha^{-1})	26540	16341	21440
Grain/unit of input energy (kg GJ^{-1})	178	126	152
Output/input ratio	5.2	3.7	4.4
Flax			
Seed Yield (Mg ha^{-1})	2.02	1.32	1.67
Gross energy output (MJ ha^{-1})	46313	29683	37998
Net energy output (MJ ha^{-1})	39435	23293	31364
Grain/unit of input energy (kg GJ^{-1})	280	205	242
Output/input ratio	7.0	5.0	6.0
Wheat			
Seed Yield (Mg ha^{-1})	2.16	1.47	1.82
Gross energy output (MJ ha^{-1})	32900	21596	27248
Net energy output (MJ ha^{-1})	26386	15184	20785
Grain/unit of input energy (kg GJ^{-1})	293	222	258
Output/input ratio	5.0	3.7	4.4

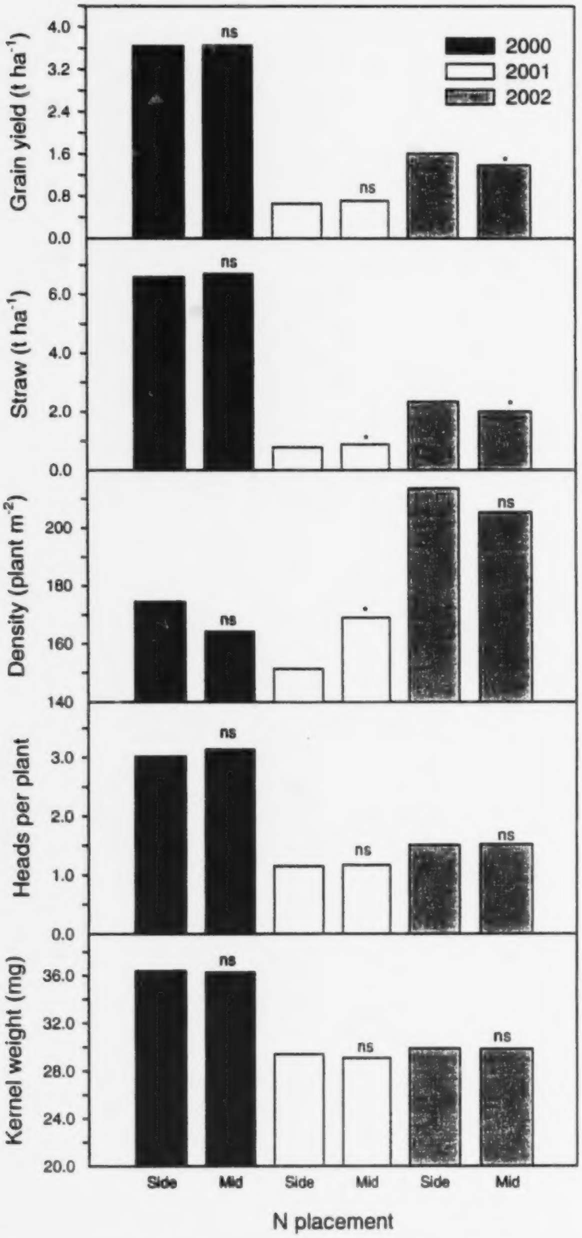

Fig. 1. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatments in wheat at Swift Current. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

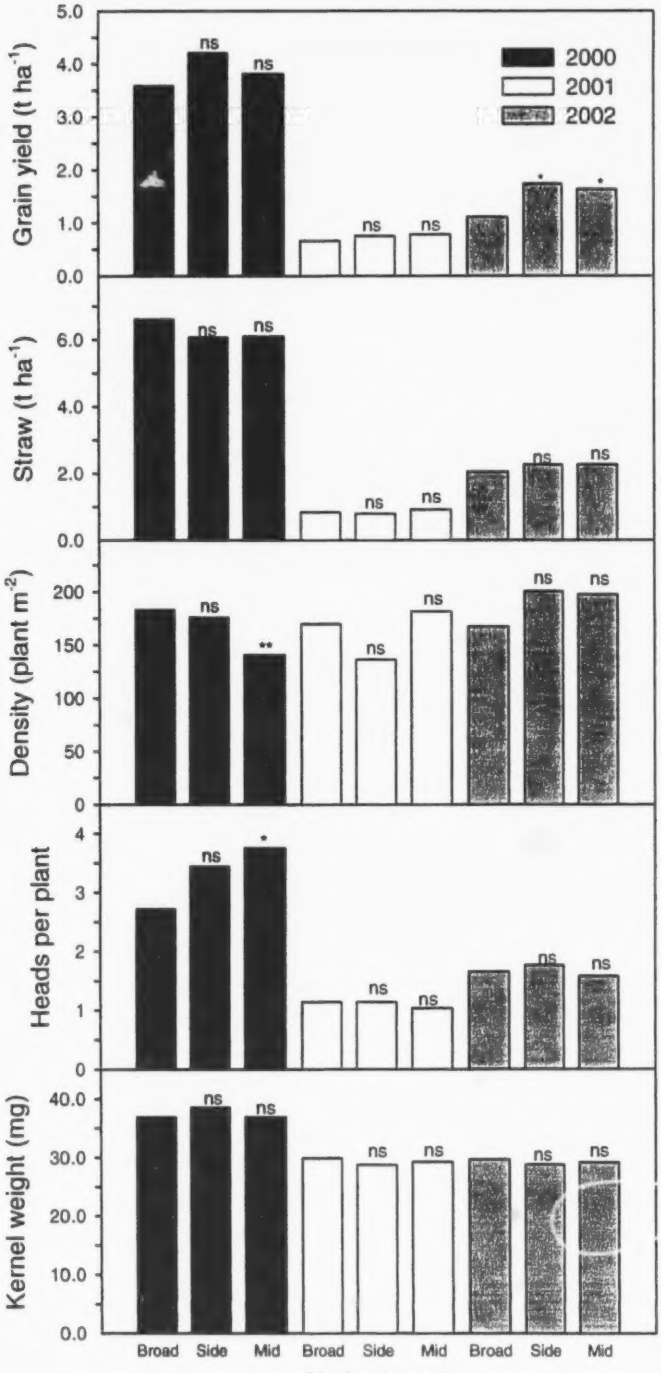

Fig. 2. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in wheat at Swift Current. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

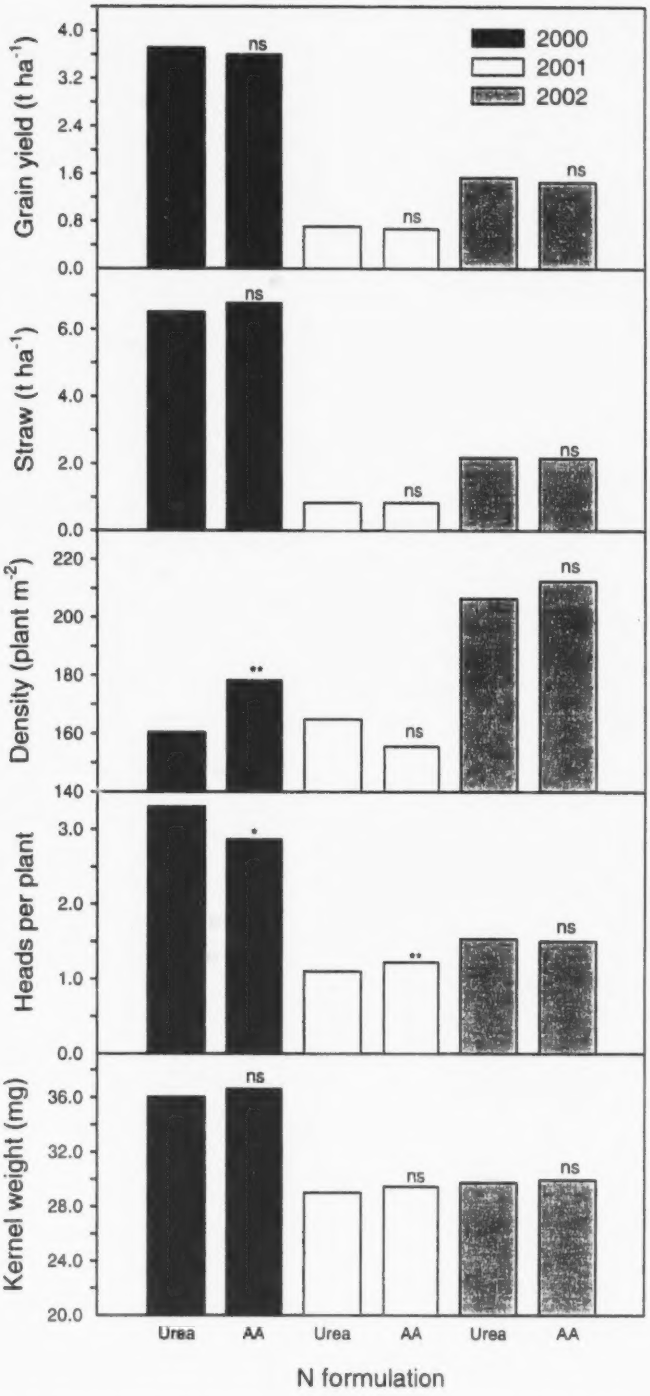

Fig. 3. Comparisons between Urea ad AA treatments in wheat at Swift Current. *, **, ns: significant at 0.05 and 0.01and not significant at 0.05 probability levels, respectively, within the same year.

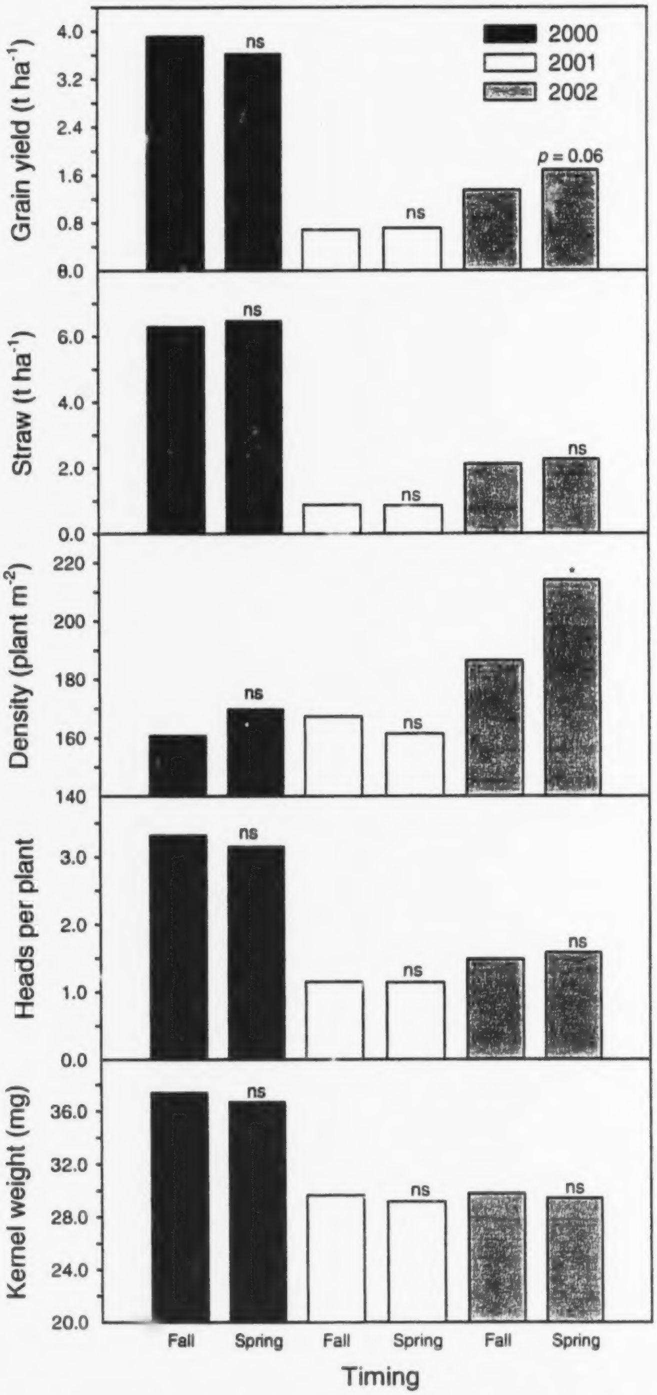

Fig. 4. Comparisons between N fertilizations in fall and in spring at medium rate in wheat at Swift Current. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

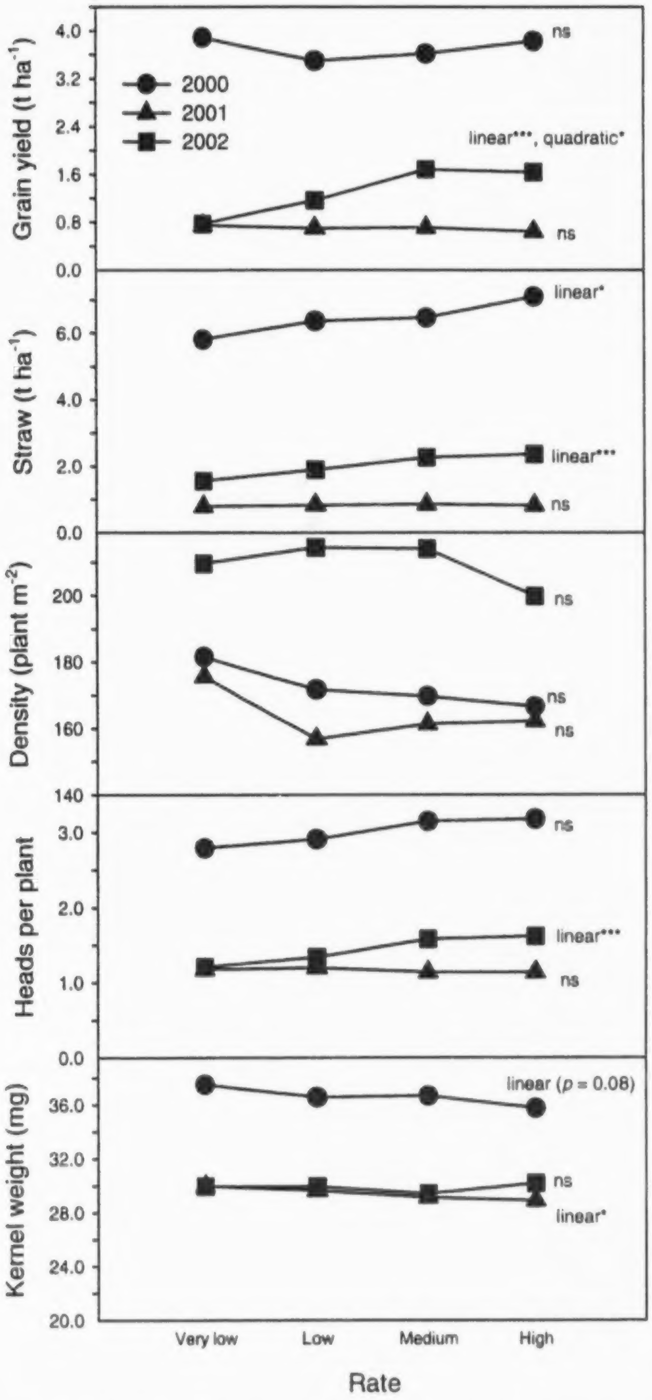

Fig. 5. Effects of N fertilizer rate on agronomic performance in wheat at Swift Current. *, **, ***, ns: significant at 0.05, 0.01 and 0.001 and not significant at 0.05 probability levels, respectively.

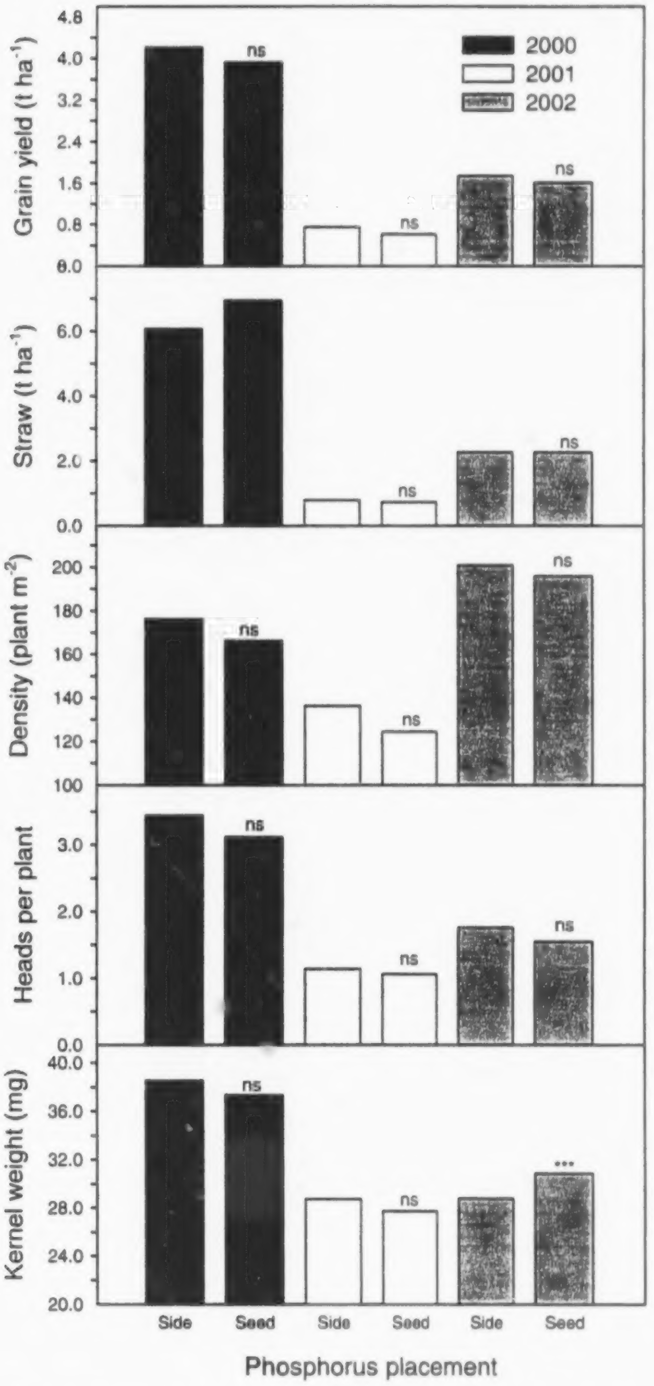

Fig. 6. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in wheat at Swift Current. ***, ns: significant at 0.001 and not significant at 0.05 probability levels, respectively, within the same year.

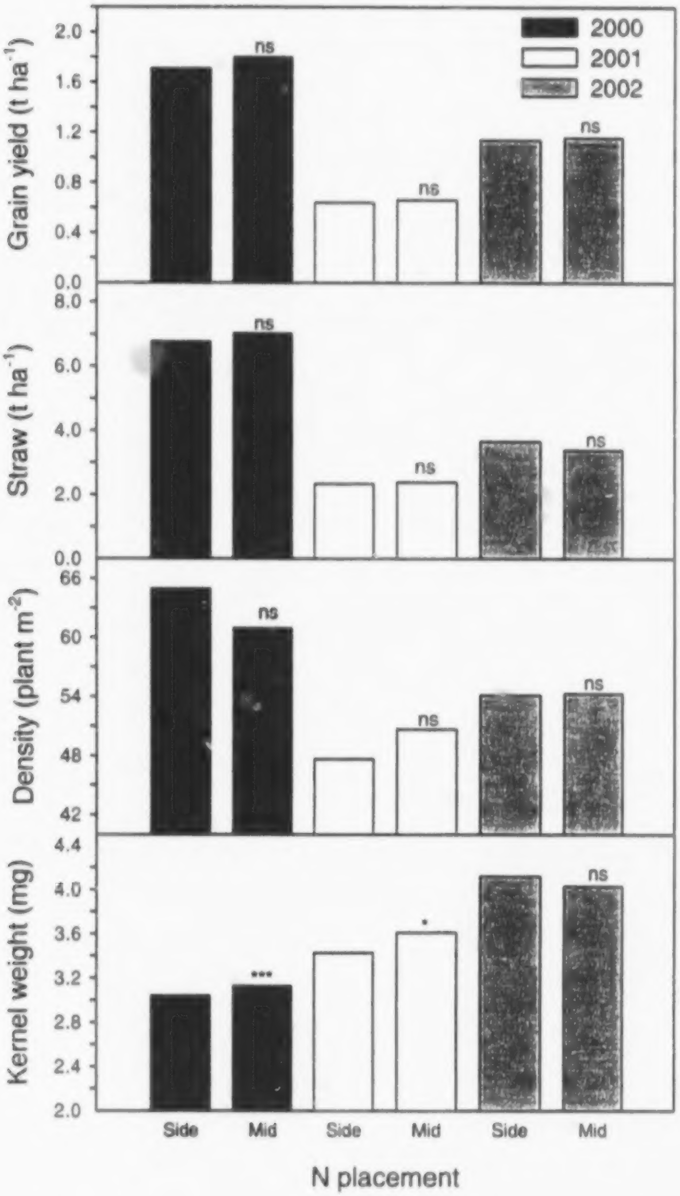

Fig. 7. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatments in canola at Swift Current. *, ***, ns: significant at 0.05, 0.001 and not significant at 0.05 probability levels, respectively, within the same year.

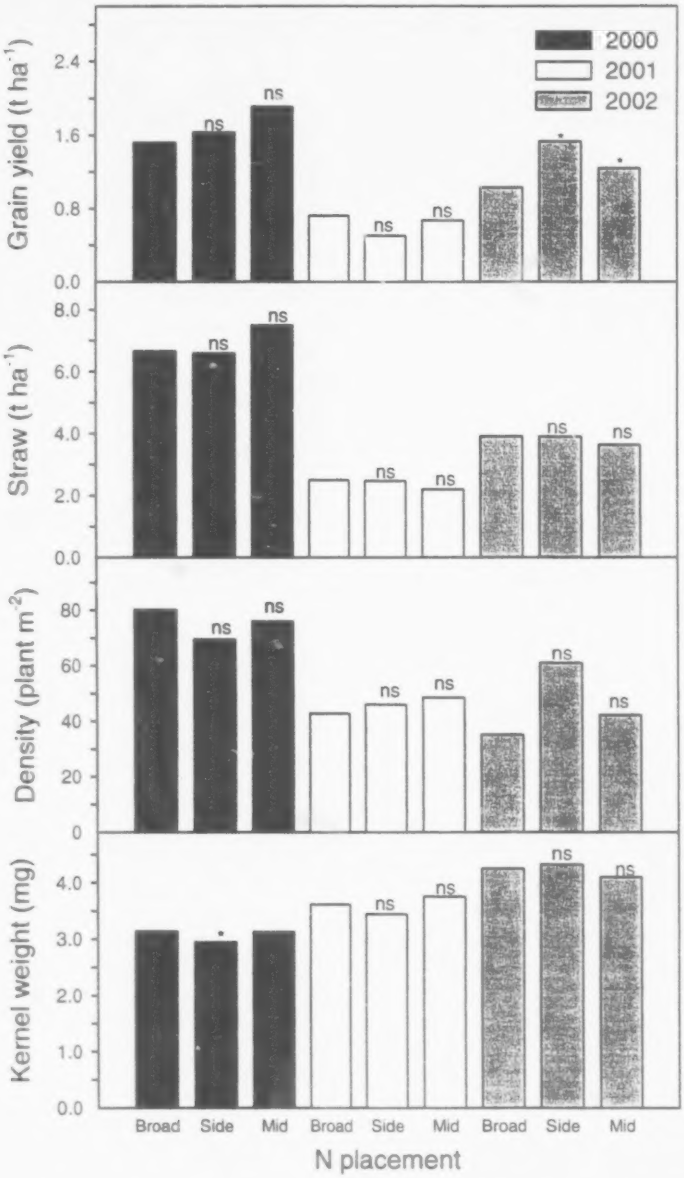

Fig. 8. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in canola at Swift Current. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

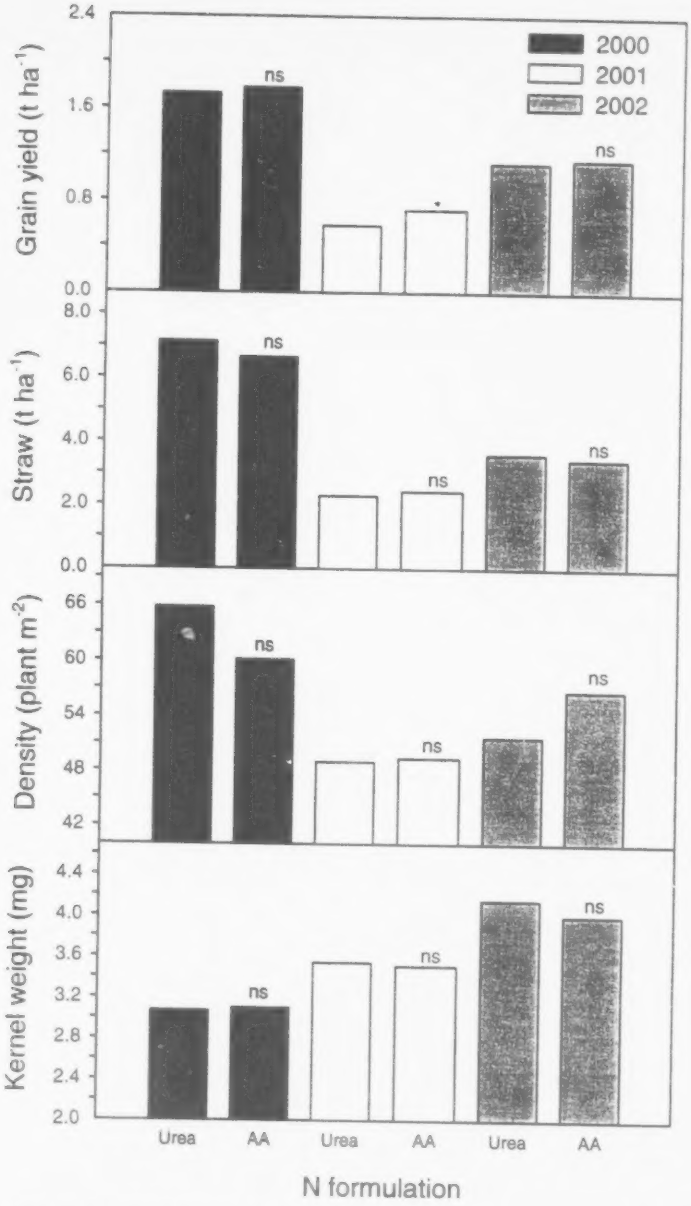

Fig. 9. Comparisons between Urea ad AA treatments in canola at Swift Current. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

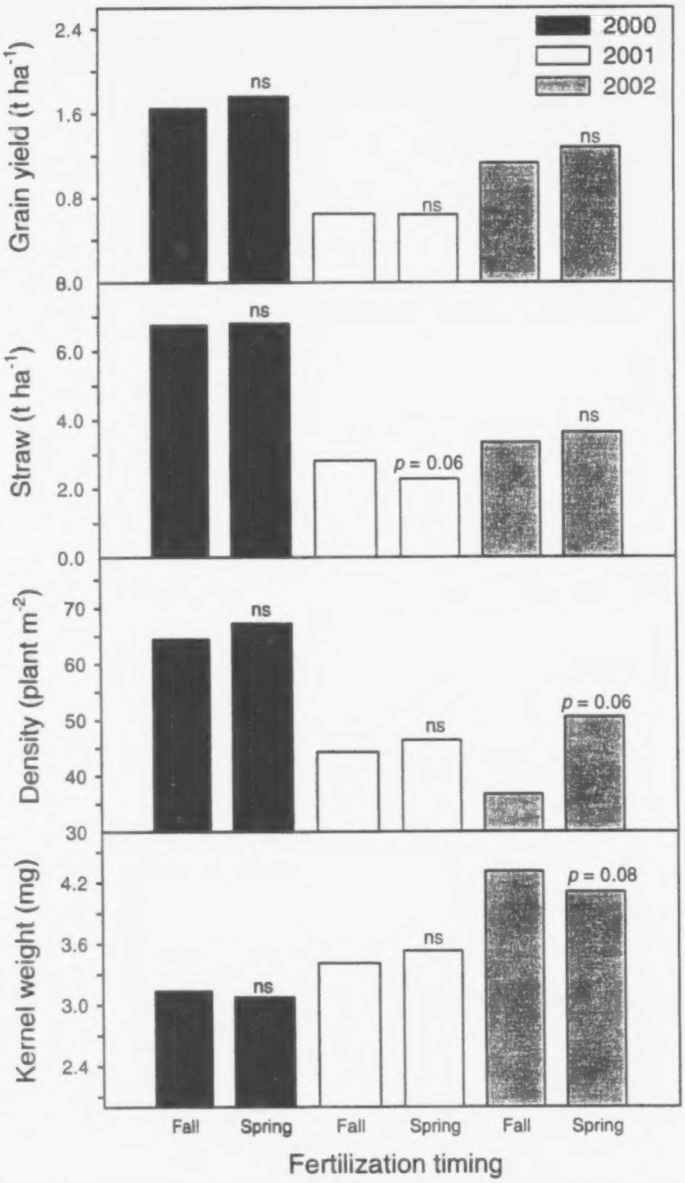

Fig. 10. Comparisons between N fertilizations in fall and in spring at medium rate in canola at Swift Current. ns: not significant at 0.05 probability level, within the same year.

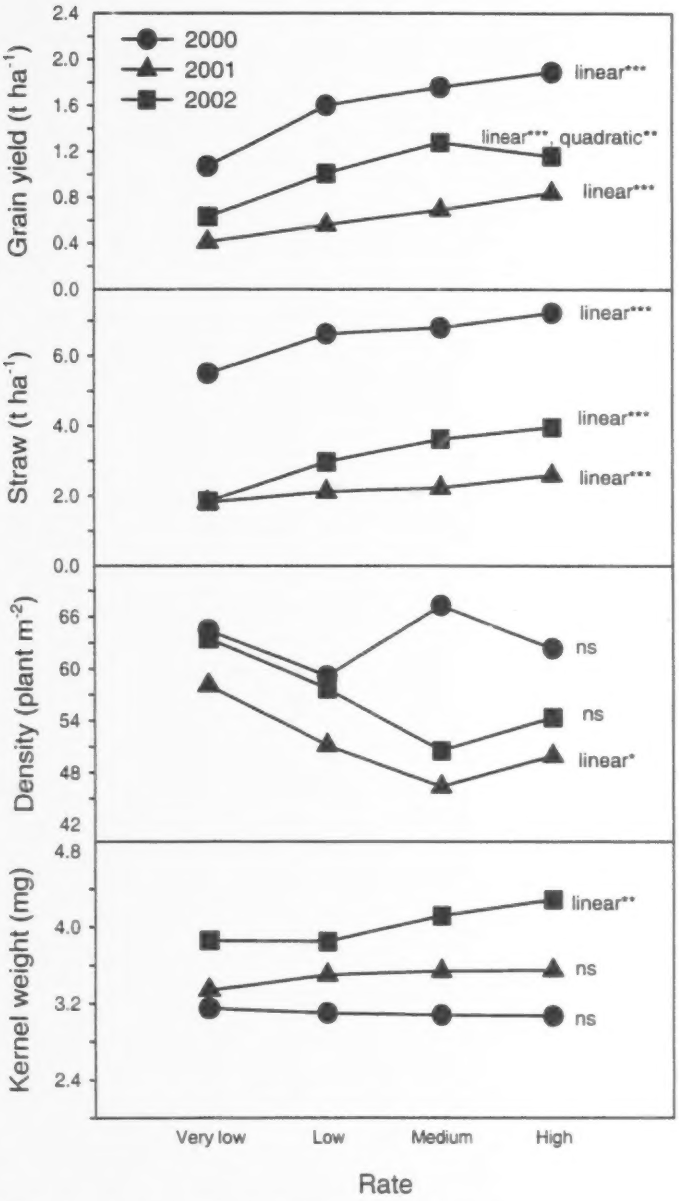

Fig. 11. Effects of N fertilizer rate on agronomic performance in canola at Swift Current. *, **, ***, ns: significant at 0.05, 0.01 and 0.001 and not significant at 0.05 probability levels, respectively.

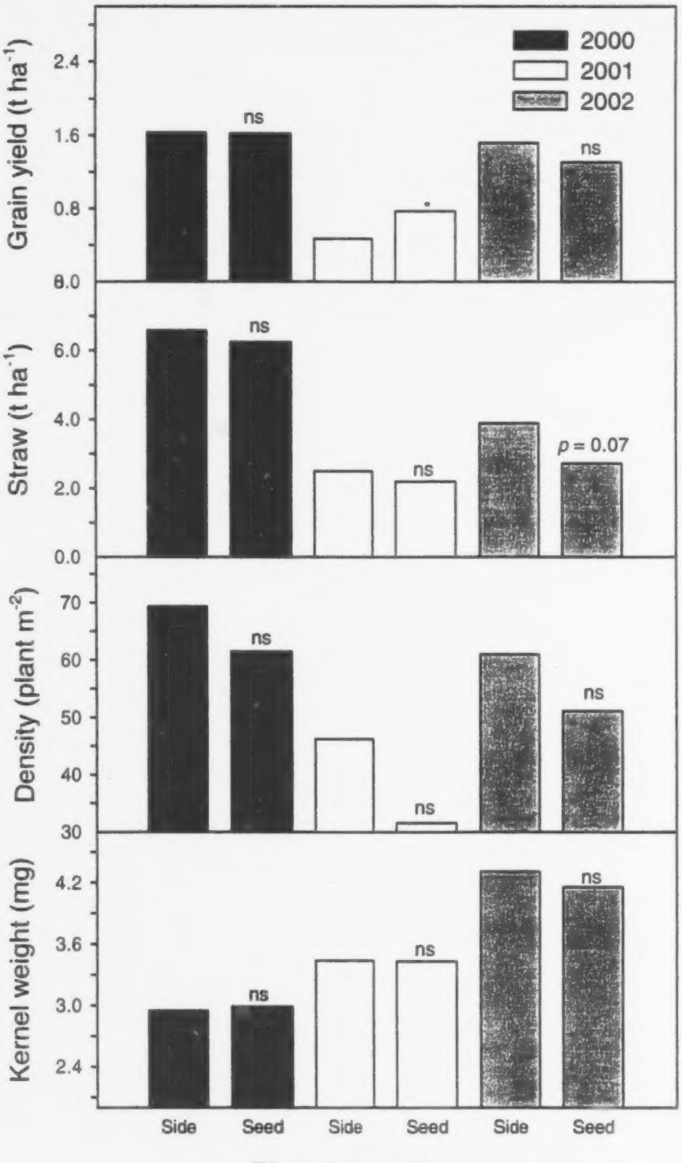

Fig. 12. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in canola at Swift Current. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

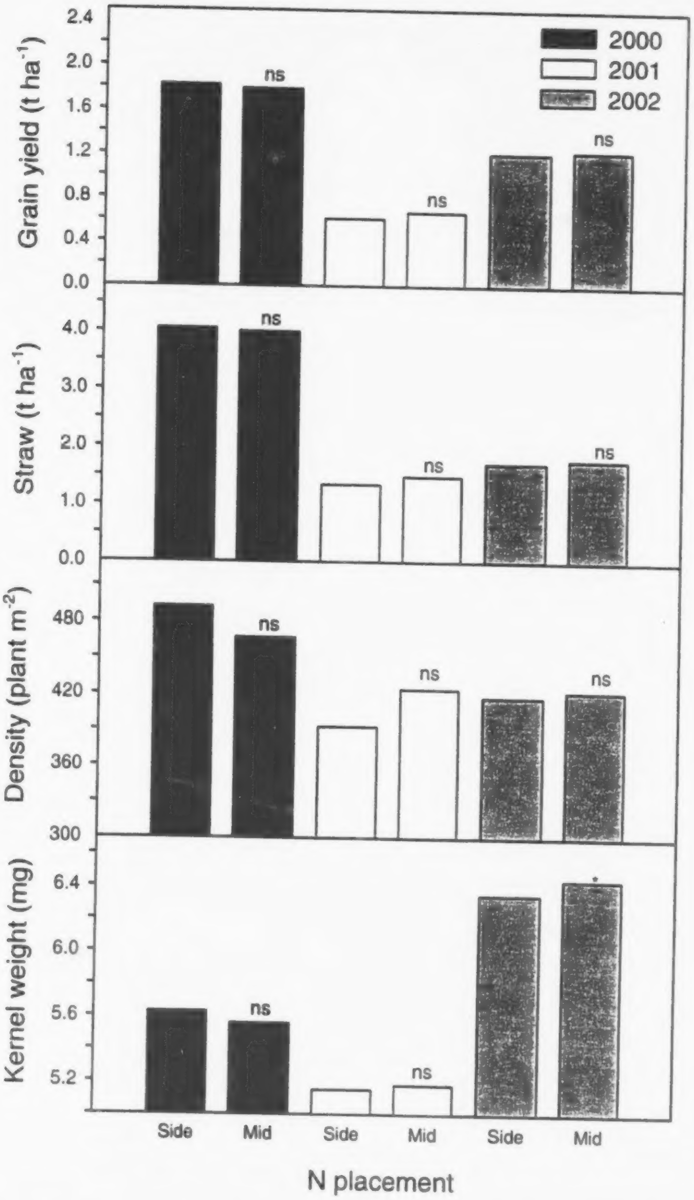

Fig. 13. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatmentsin flax at Swift Current. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

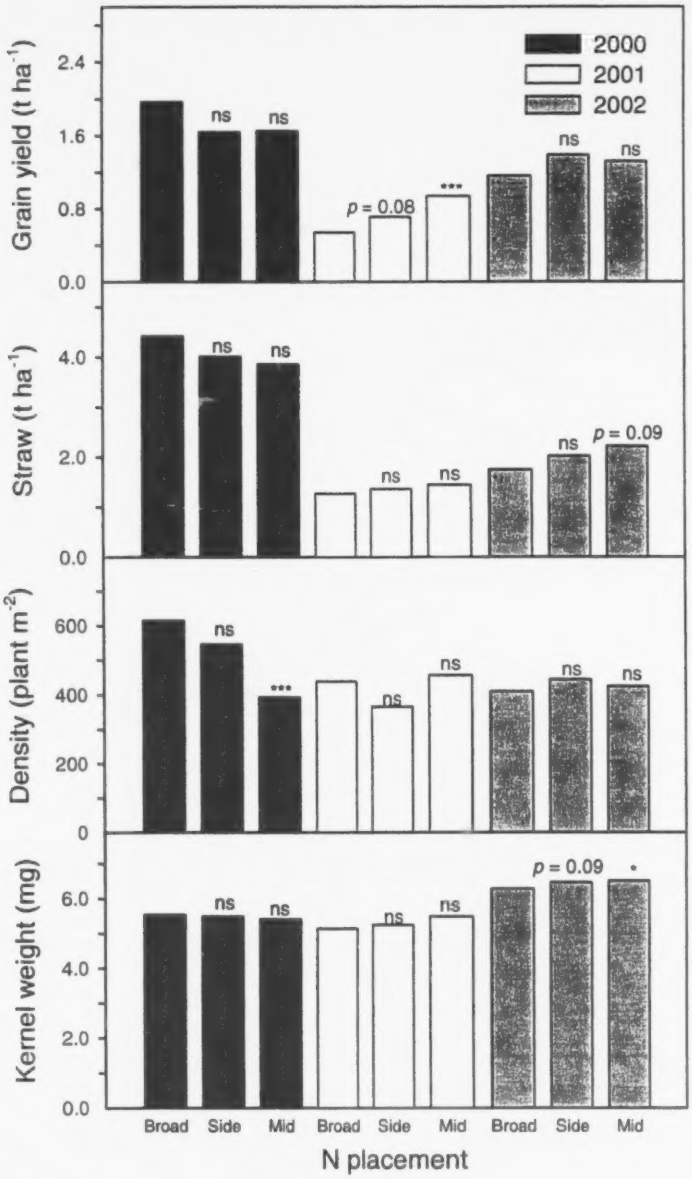

Fig. 14. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in flax at Swift Current. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

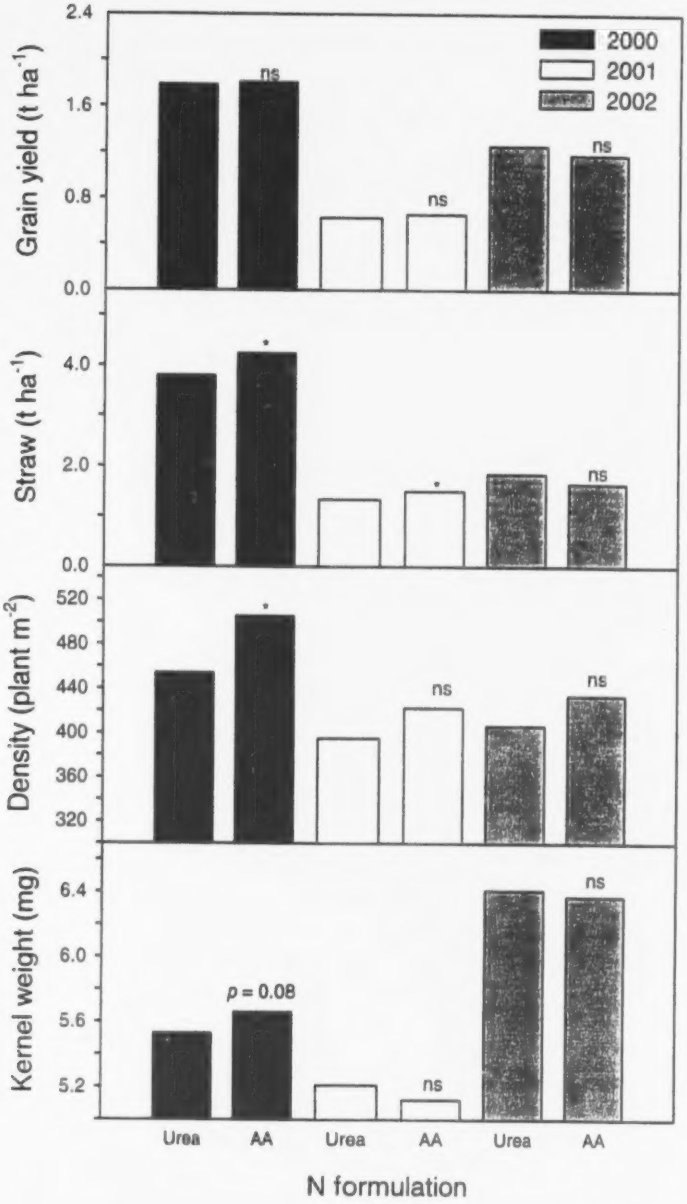

Fig. 15. Comparisons between Urea ad AA treatments in flax at Swift Current. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

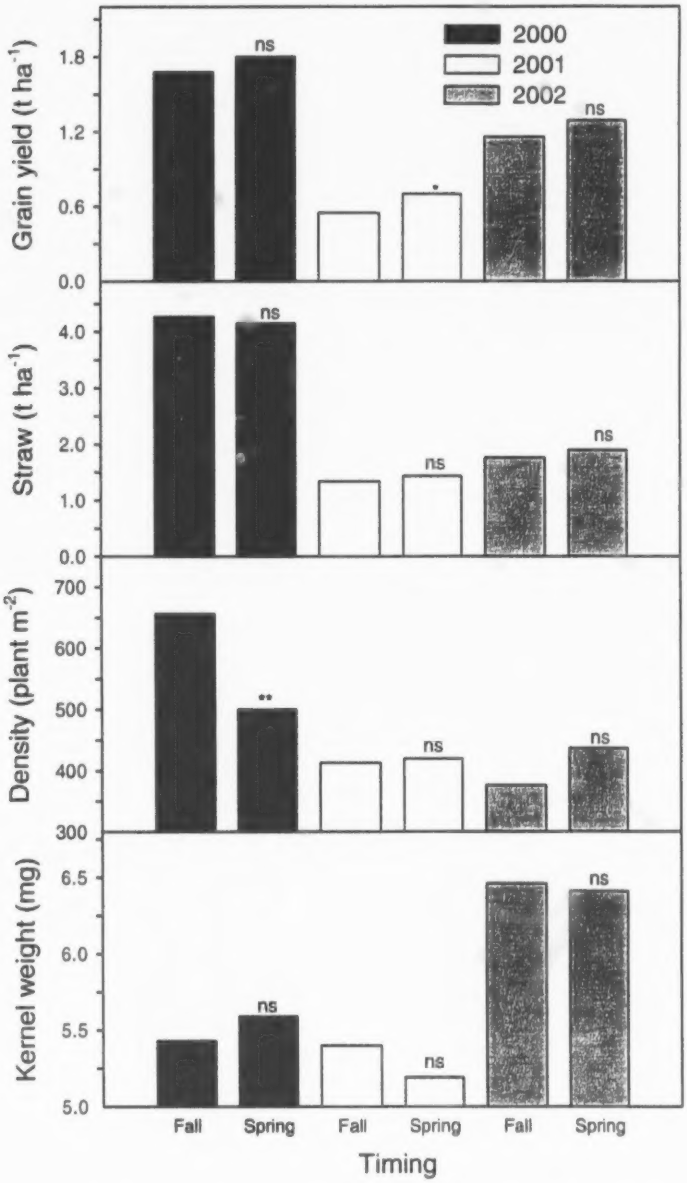

Fig. 16. Comparisons between N fertilizations in fall and in spring at medium rate in flax at Swift Current. *, **, ns: significant at 0.01, 0.05 and not significant at 0.05 probability level, within the same year.

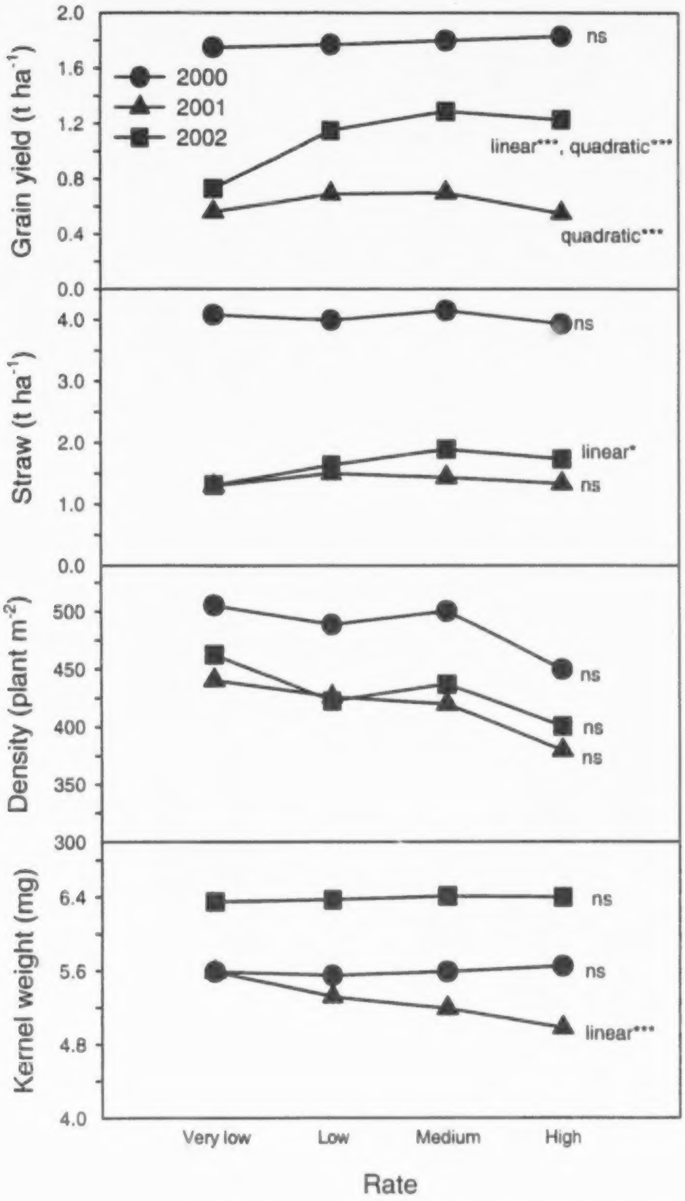

Fig. 17. Effects of N fertilizer rate on agronomic performance in flax at Swift Current. *, ***, ns: significant at 0.05 and 0.001 and not significant at 0.05 probability levels, respectively.

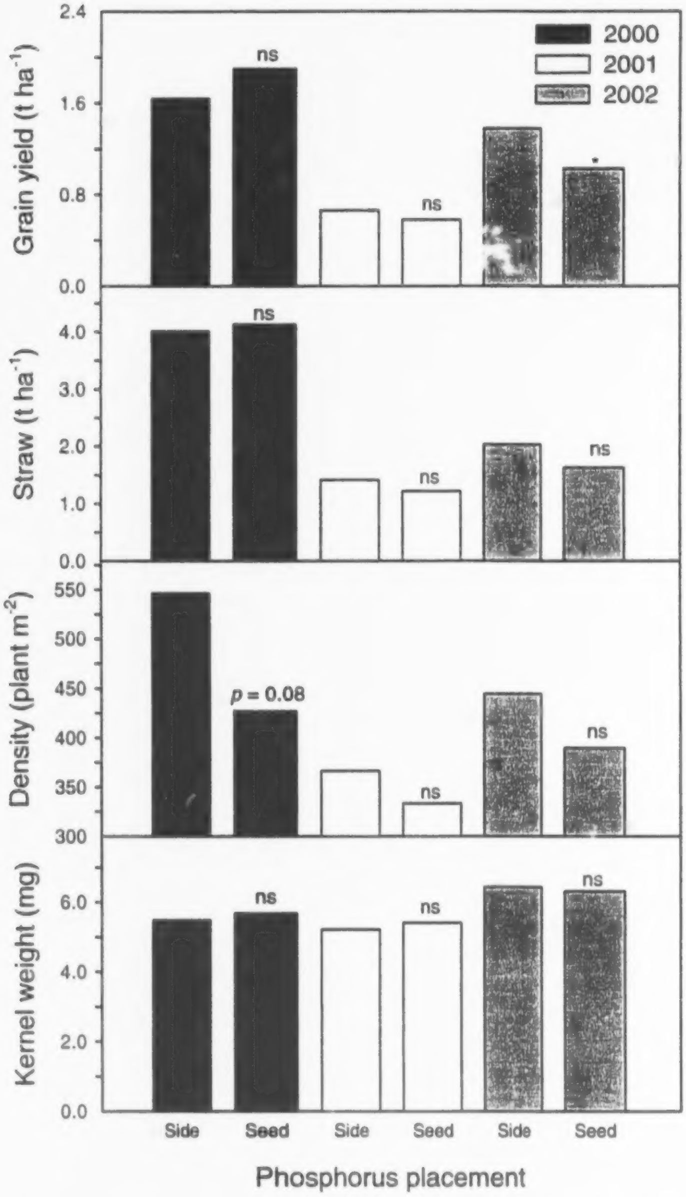

Fig. 18. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in flax at Swift Current. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

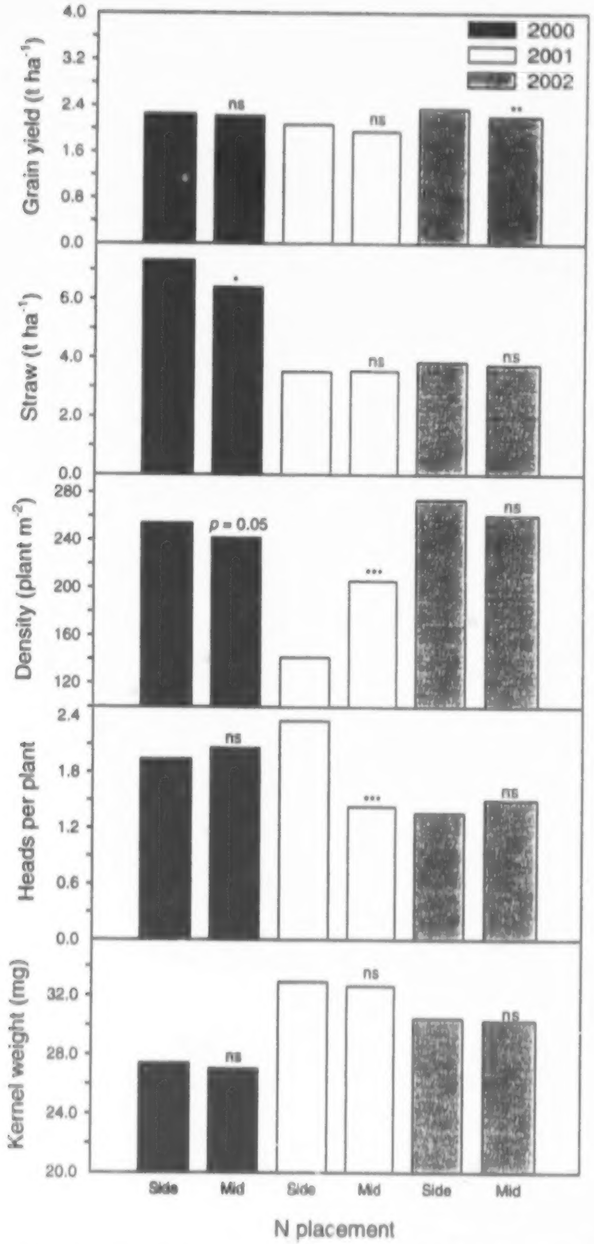

Fig. 19. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatments in wheat at Indian Head. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

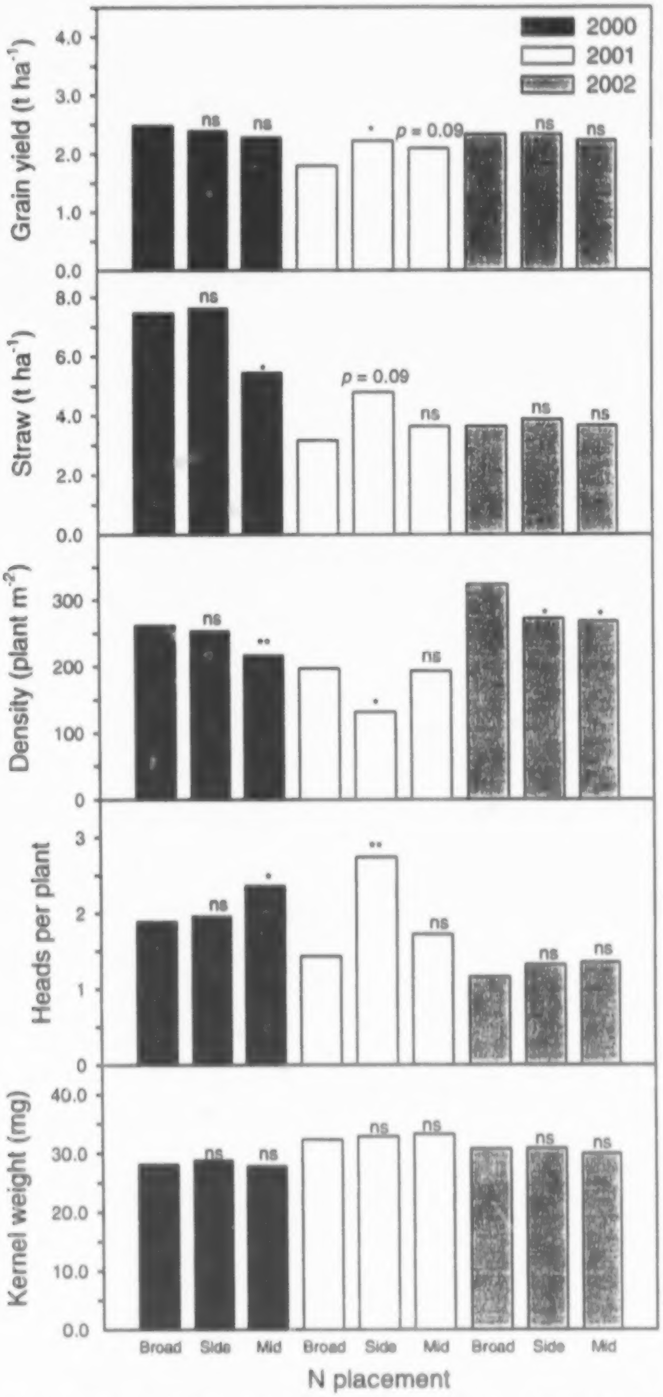

Fig. 20. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in wheat at Indian Head. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

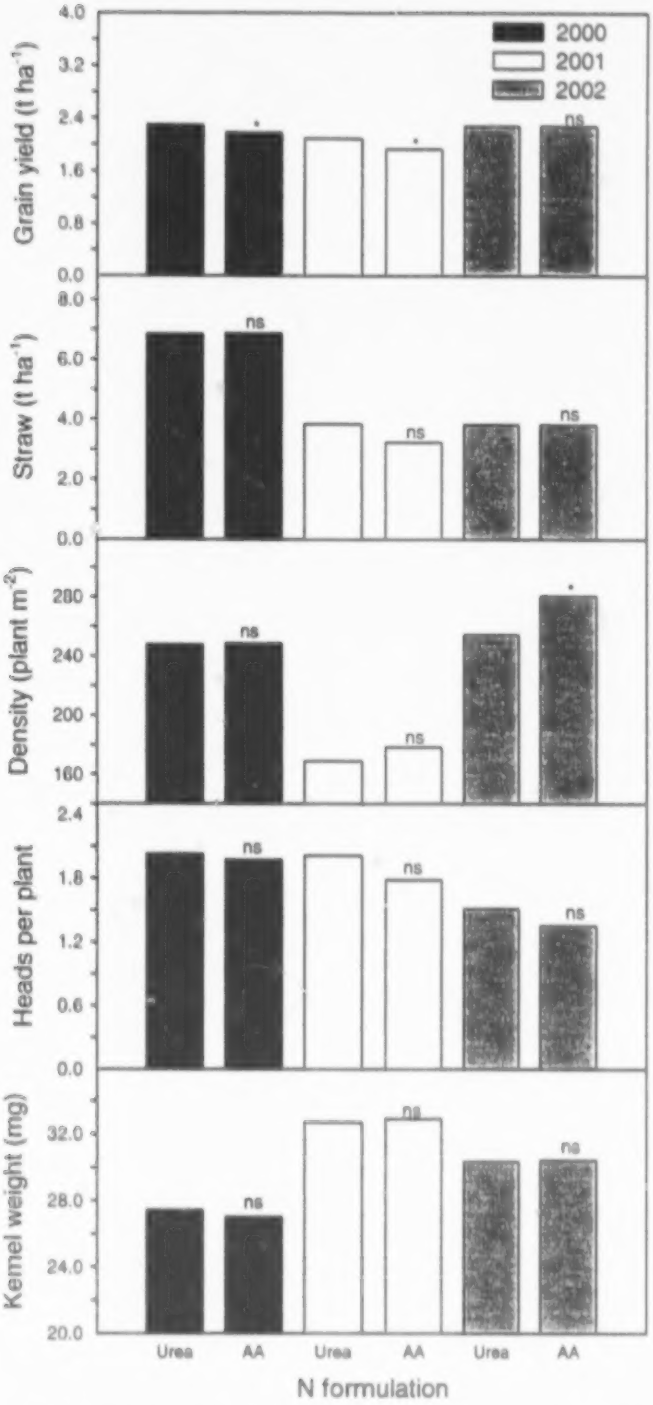

Fig. 21. Comparisons between Urea ad AA treatments in wheat at Indian Head. *, **, ns: significant at 0.05 and 0.01and not significant at 0.05 probability levels, respectively, within the same year.

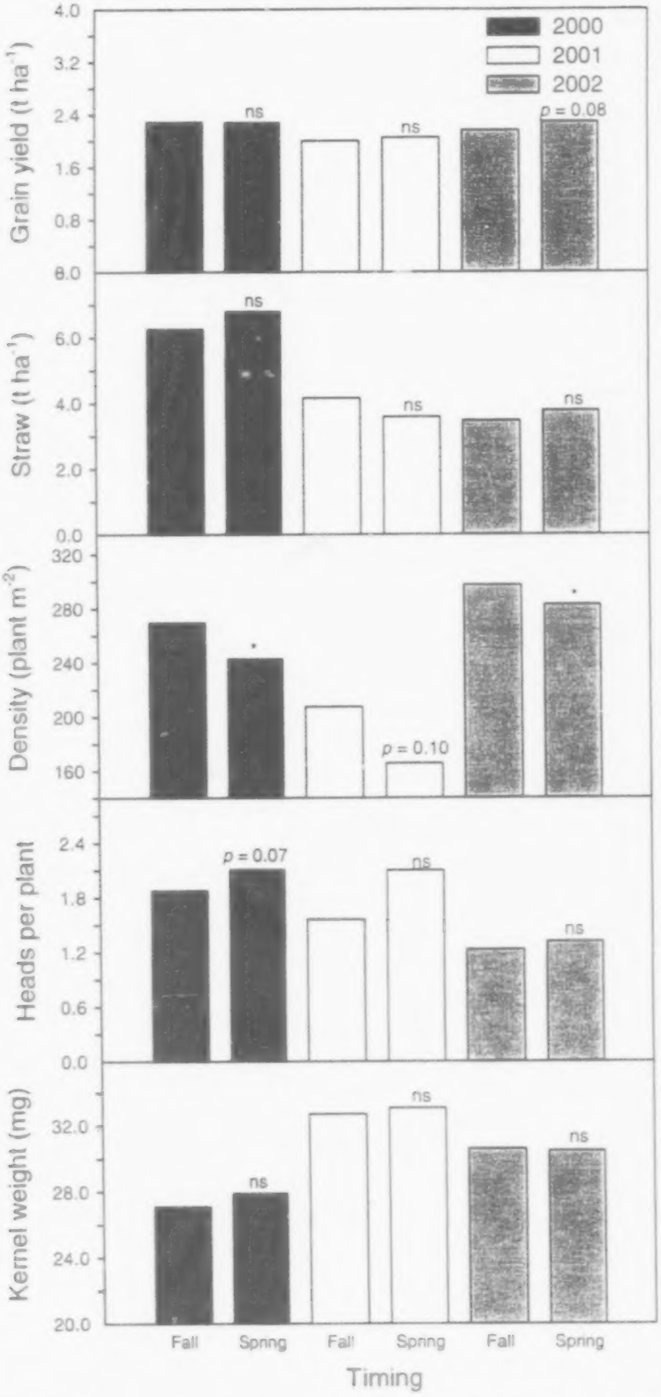

Fig. 22. Comparisons between N fertilizations in fall and in spring at medium rate in wheat at Indian Head. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

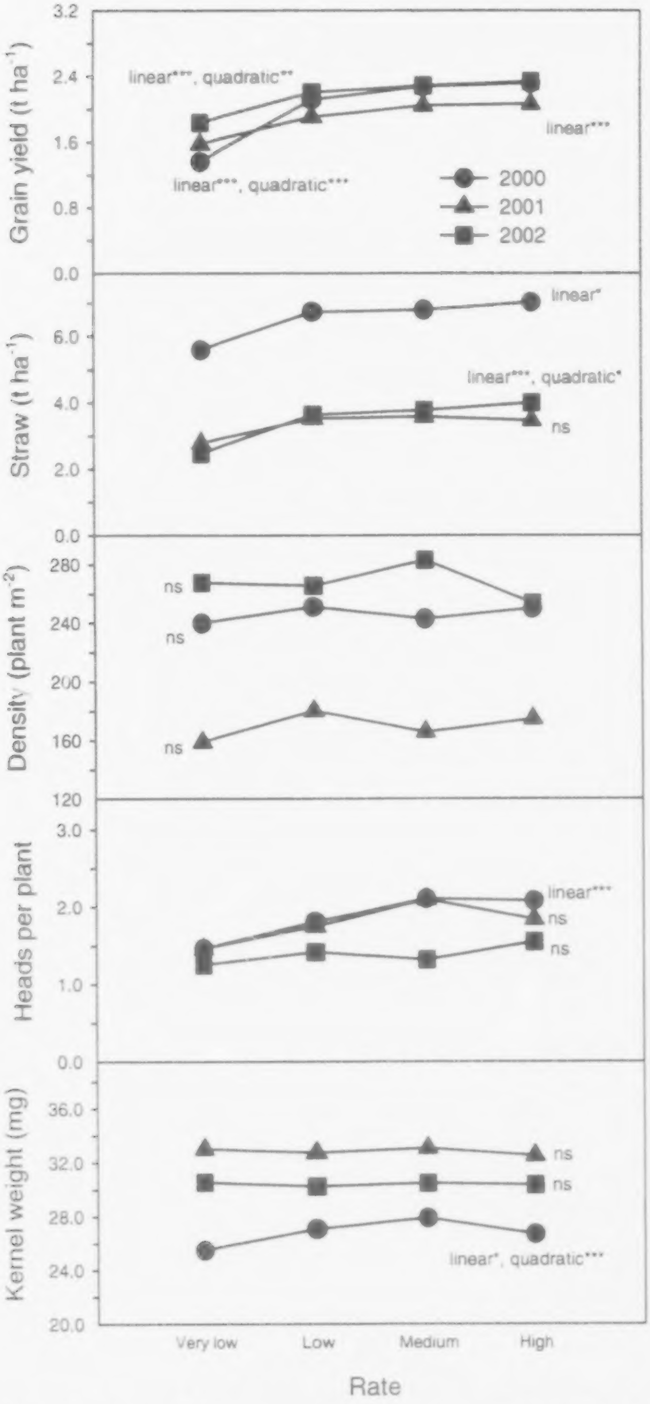

Fig. 23. Effects of N fertilizer rate on agronomic performance in wheat at Indian Head. *, **, ***, ns: significant at 0.05, 0.01 and 0.001 and not significant at 0.05 probability levels, respectively.

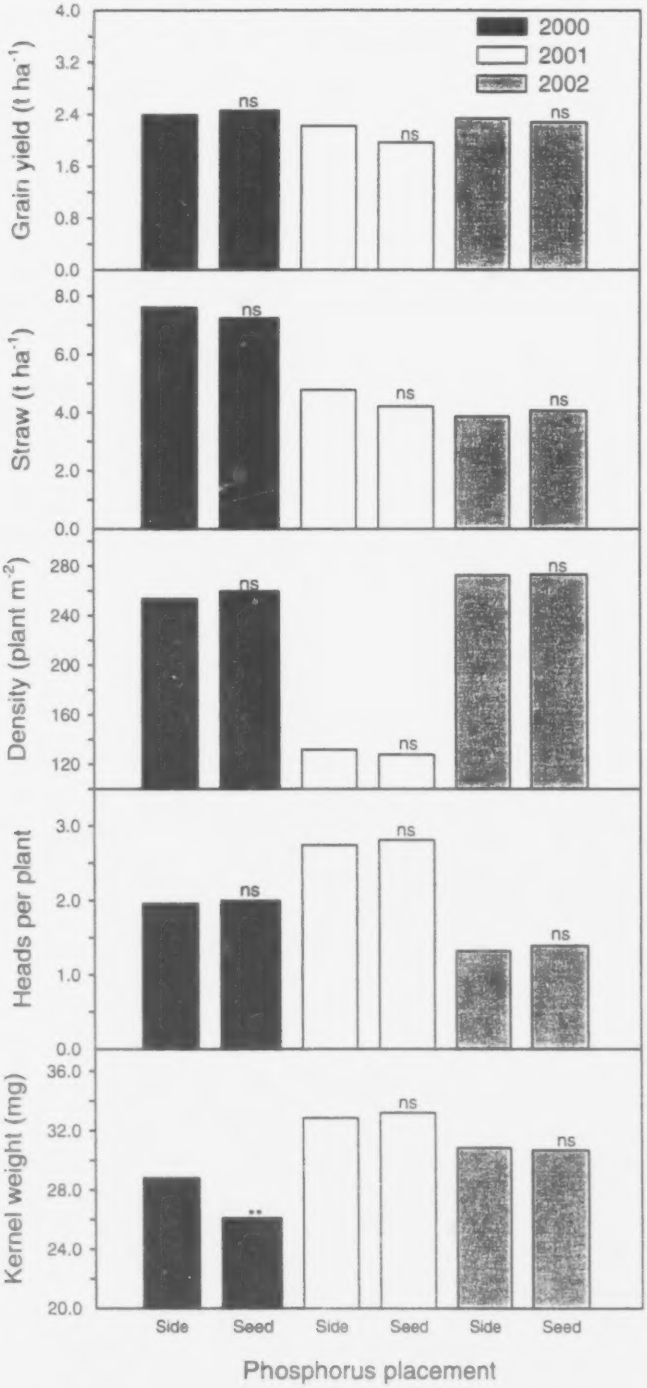

Fig. 24. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in wheat at Indian Head. ***, ns: significant at 0.001 and not significant at 0.05 probability levels, respectively, within the same year.

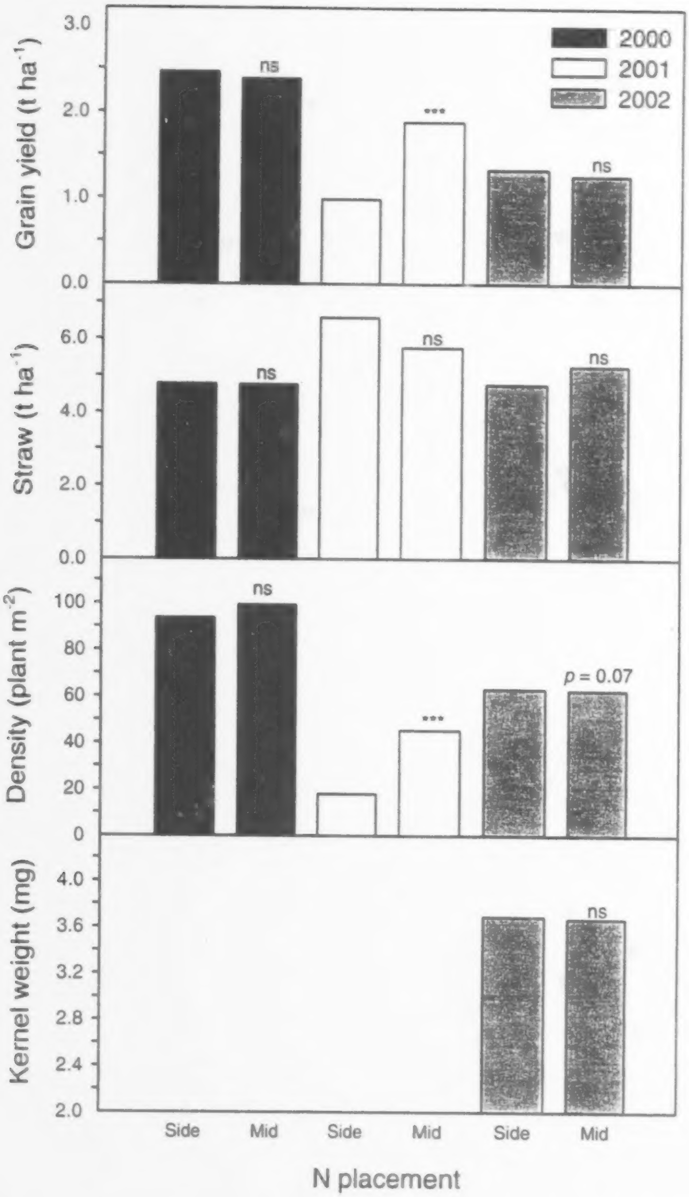

Fig. 25. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatments in canola at Indian Head. *, ***, ns: significant at 0.05, 0.001 and not significant at 0.05 probability levels, respectively, within the same year.

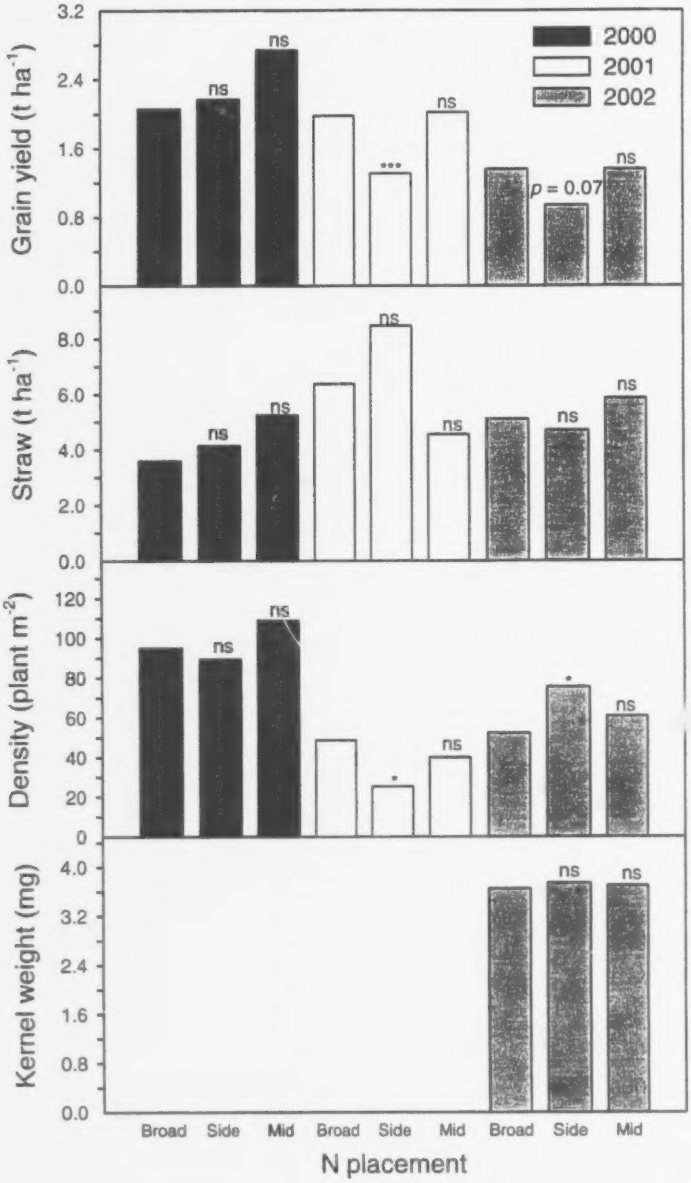

Fig. 26. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in canola at Indian Head. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

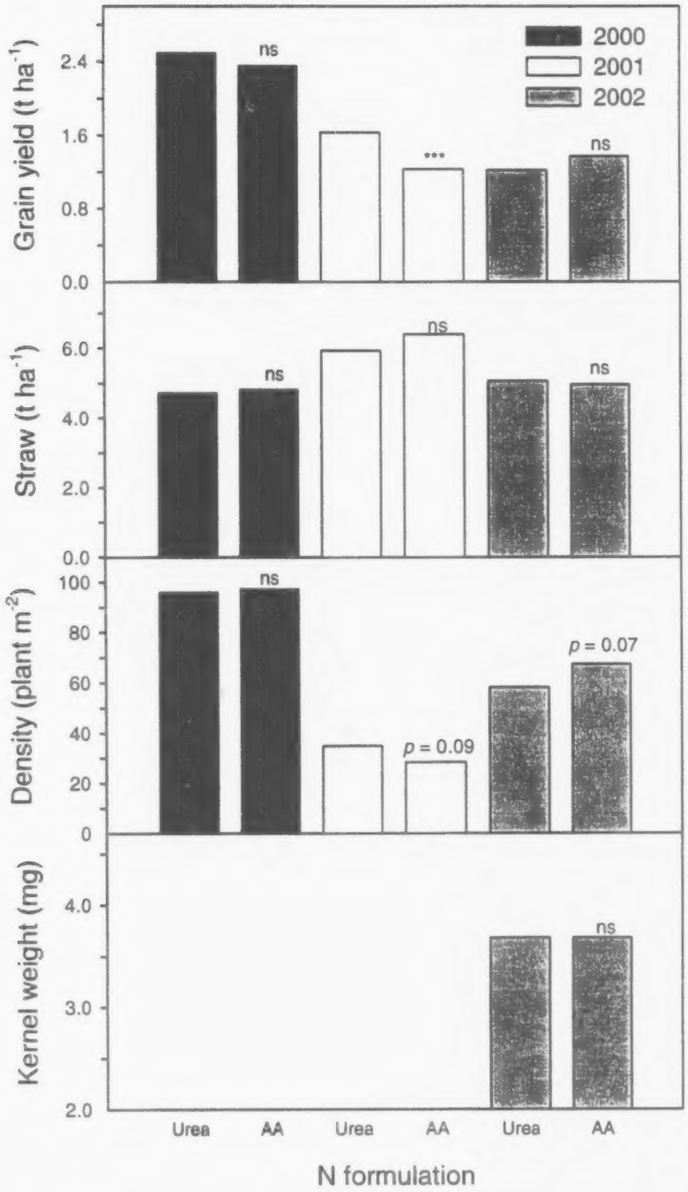

Fig. 27. Comparisons between Urea ad AA treatments in canola at Indian Head. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

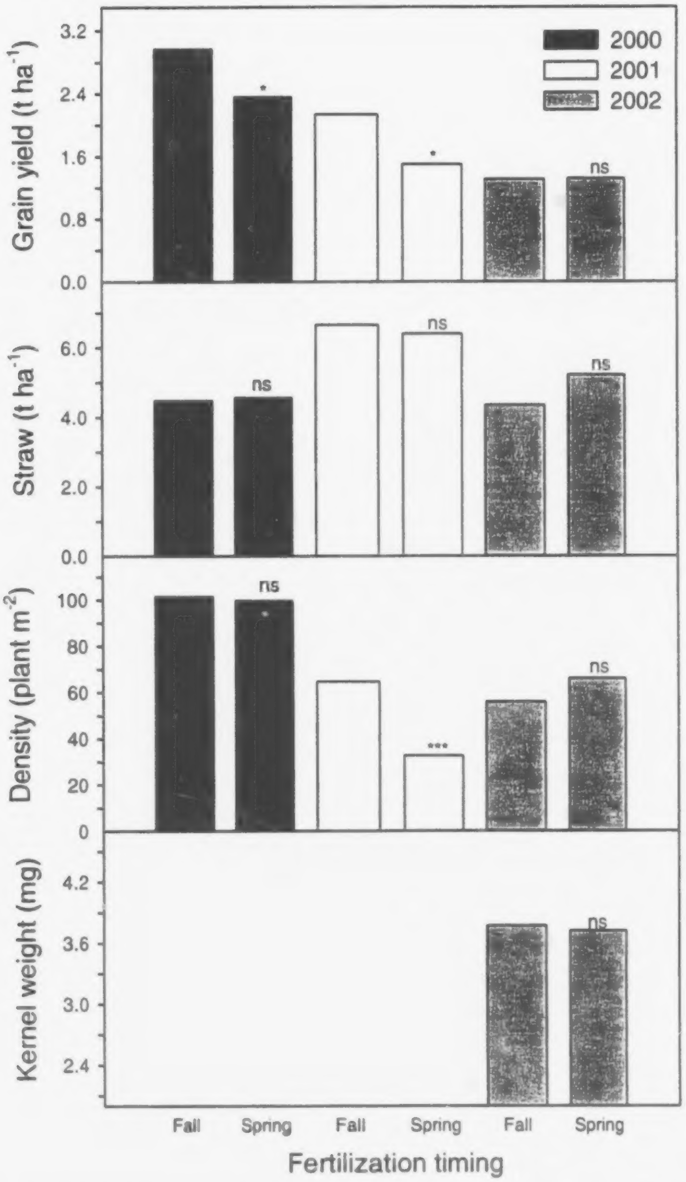

Fig. 28. Comparisons between N fertilizations in fall and in spring at medium rate in canola at Indian Head. ns: not significant at 0.05 probability level, within the same year.

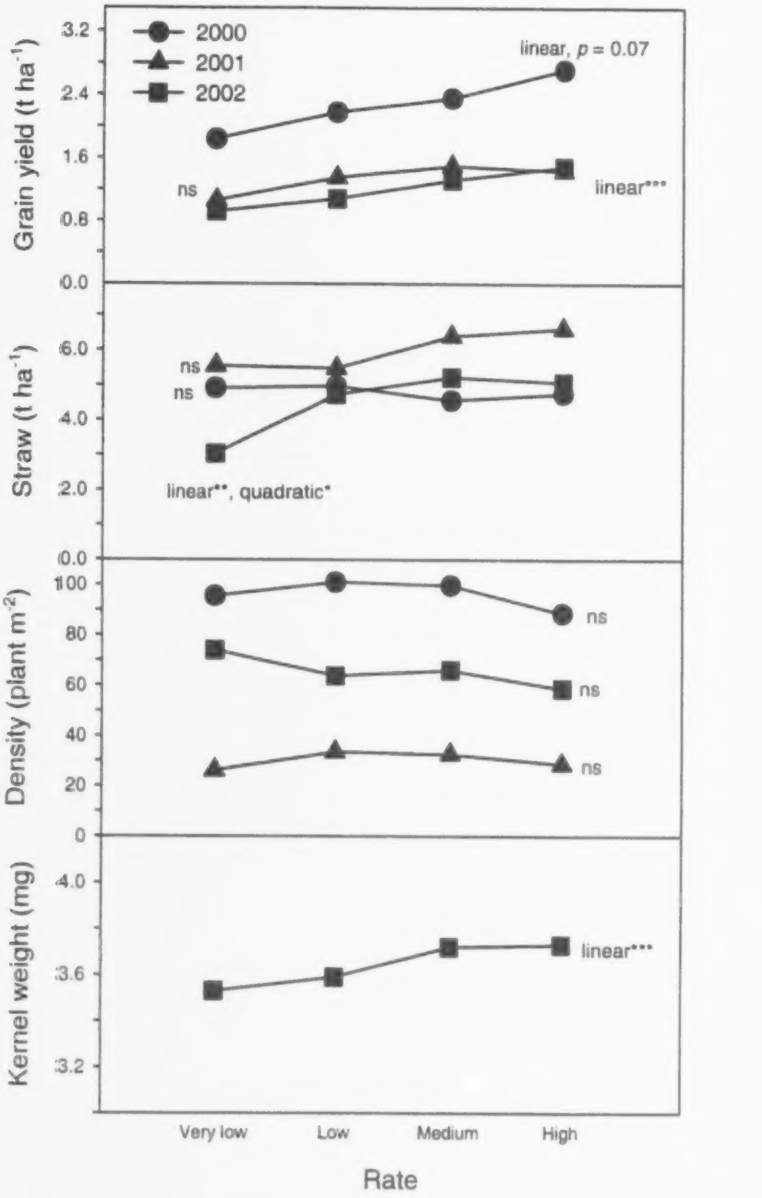

Fig. 29. Effects of N fertilizer rate on agronomic performance in canola at Indian Head. *, **, ***, ns: significant at 0.05, 0.01 and 0.001 and not significant at 0.05 probability levels, respectively.

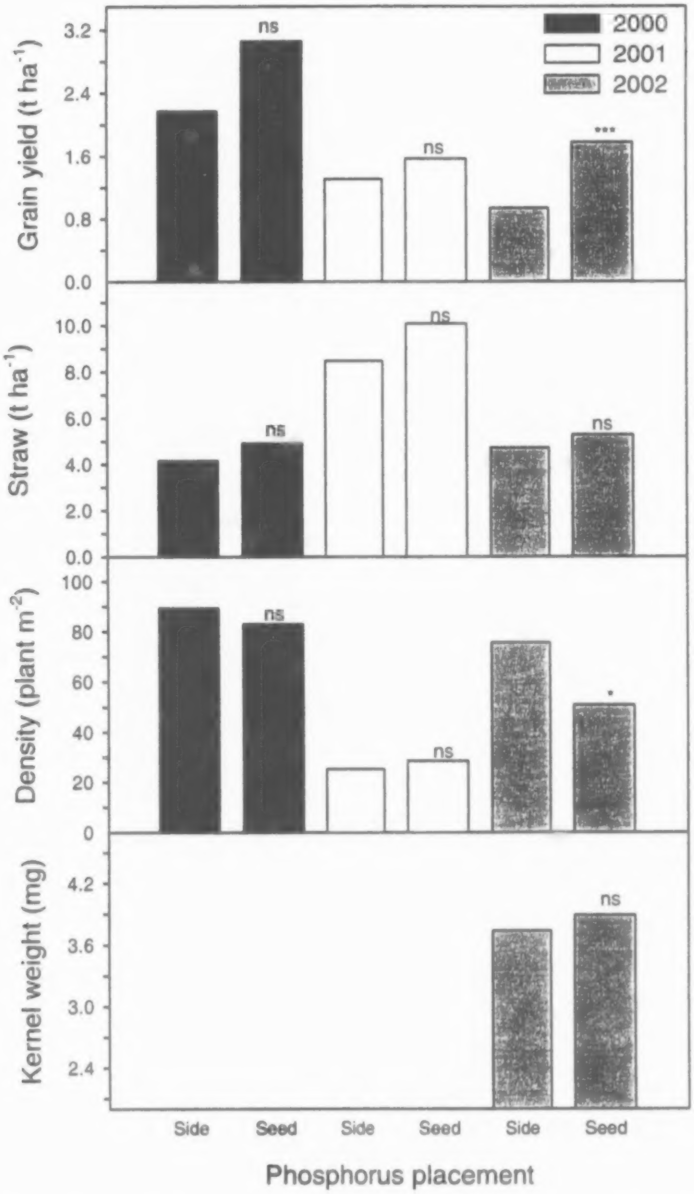

Fig. 30. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in canola at Indian Head. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

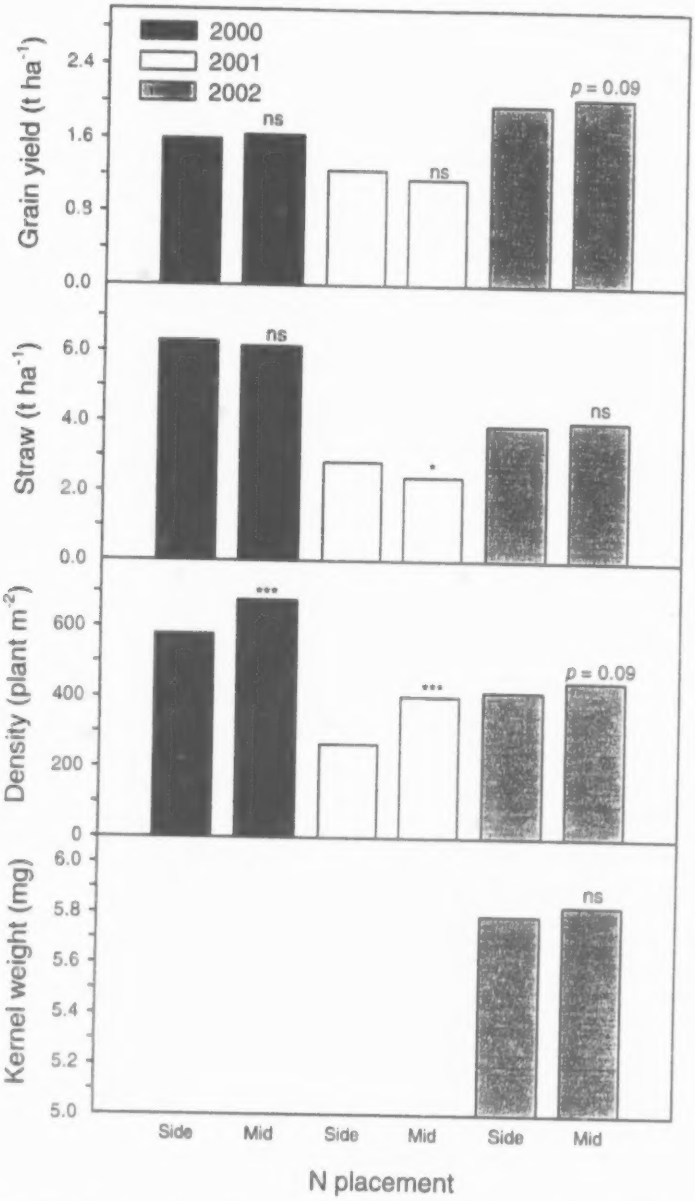

Fig. 31. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatmentsin flax at Indian Head. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

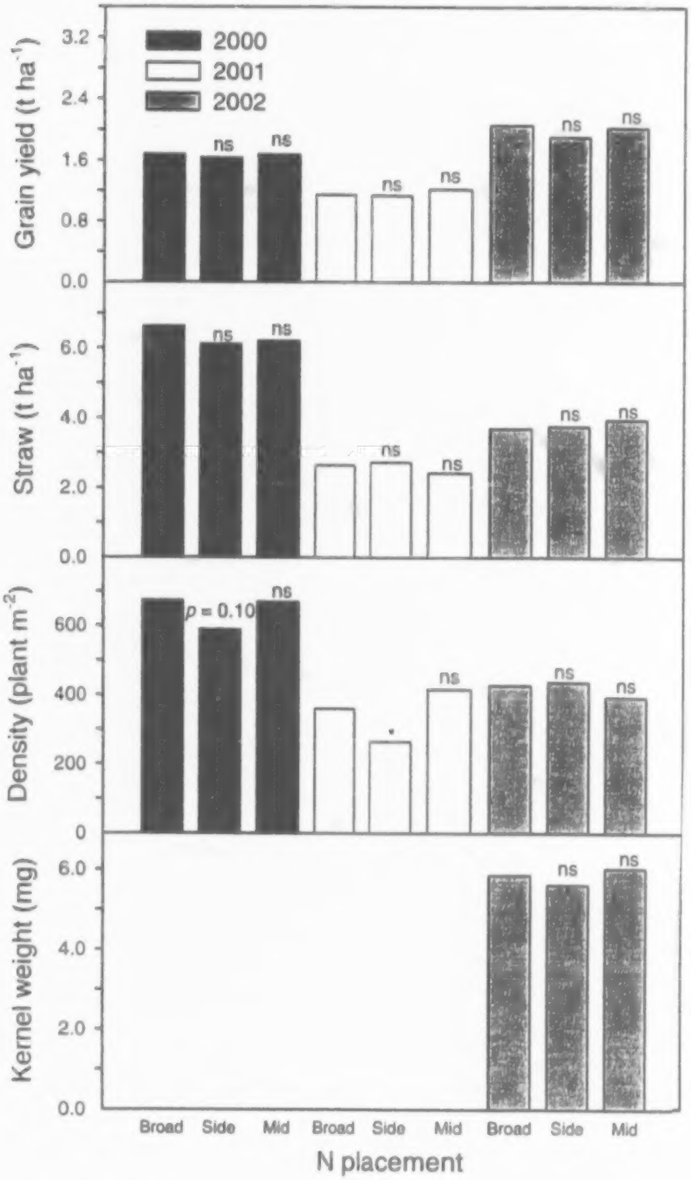

Fig. 32. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in flax at Indian Head. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

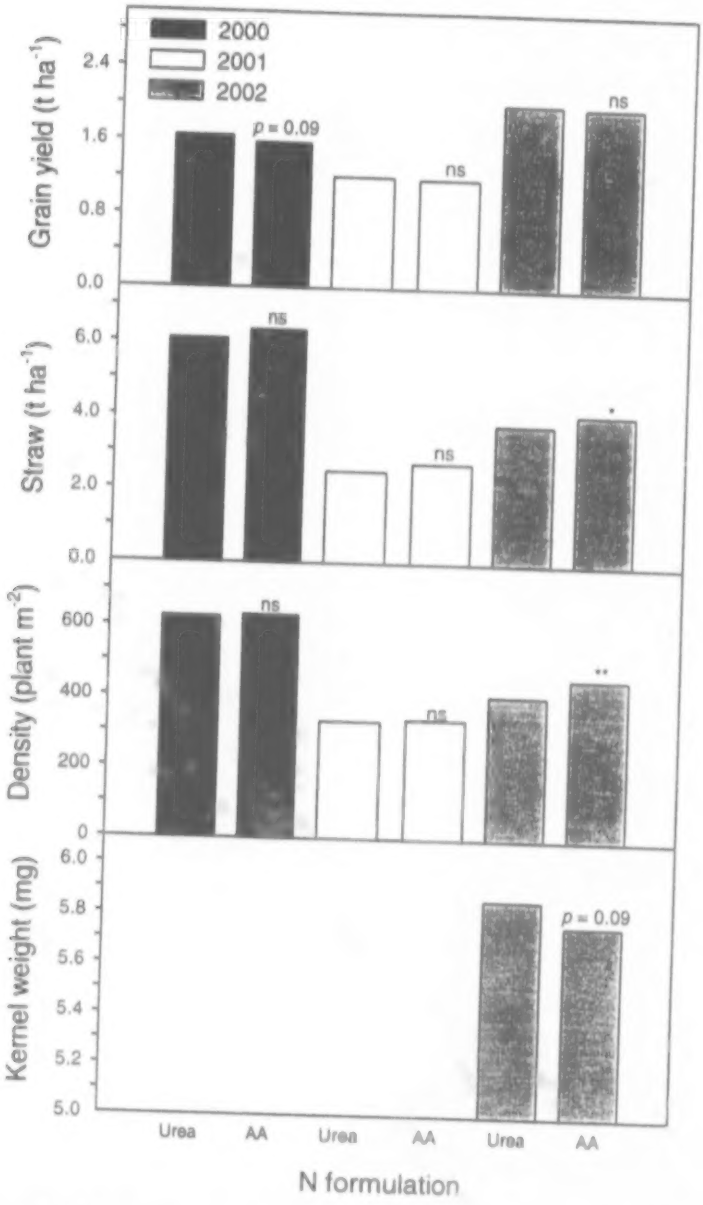

Fig. 33. Comparisons between Urea ad AA treatments in flax at Indian Head. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

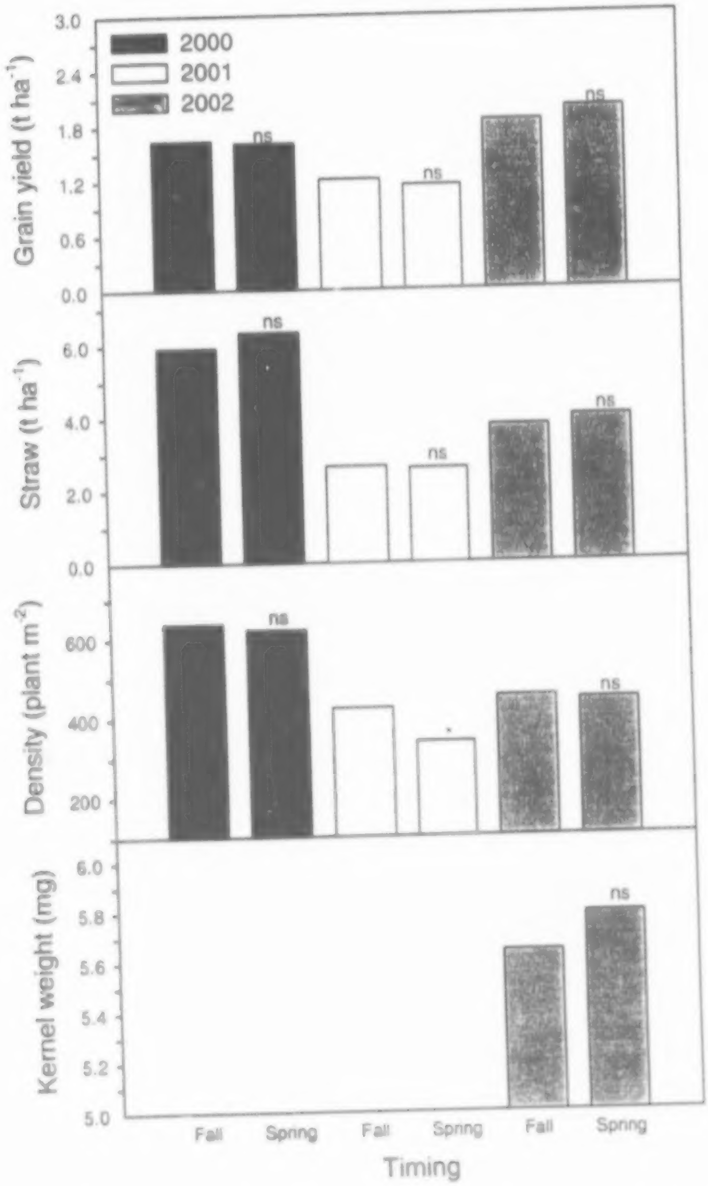

Fig. 34. Comparisons between N fertilizations in fall and in spring at medium rate in flax at Indian Head. *, **, ns: significant at 0.01, 0.05 and not significant at 0.05 probability level, within the same year.

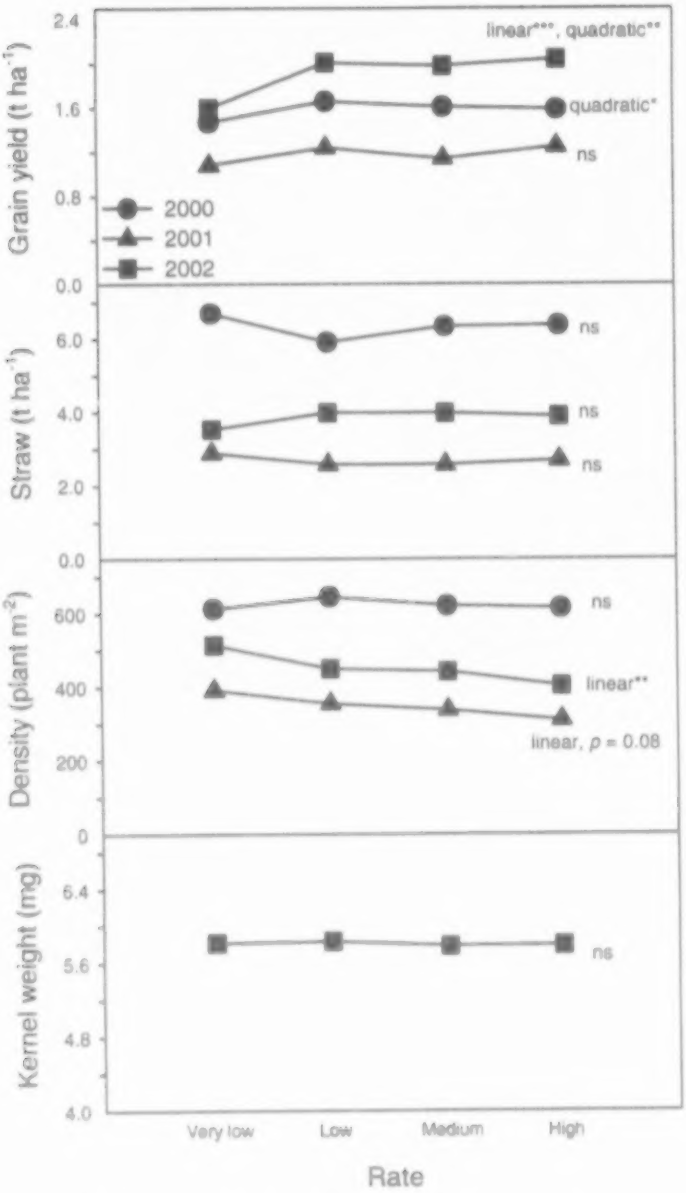

Fig. 35. Effects of N fertilizer rate on agronomic performance in flax at Indian Head. *, ***, ns: significant at 0.05 and 0.001 and not significant at 0.05 probability levels, respectively.

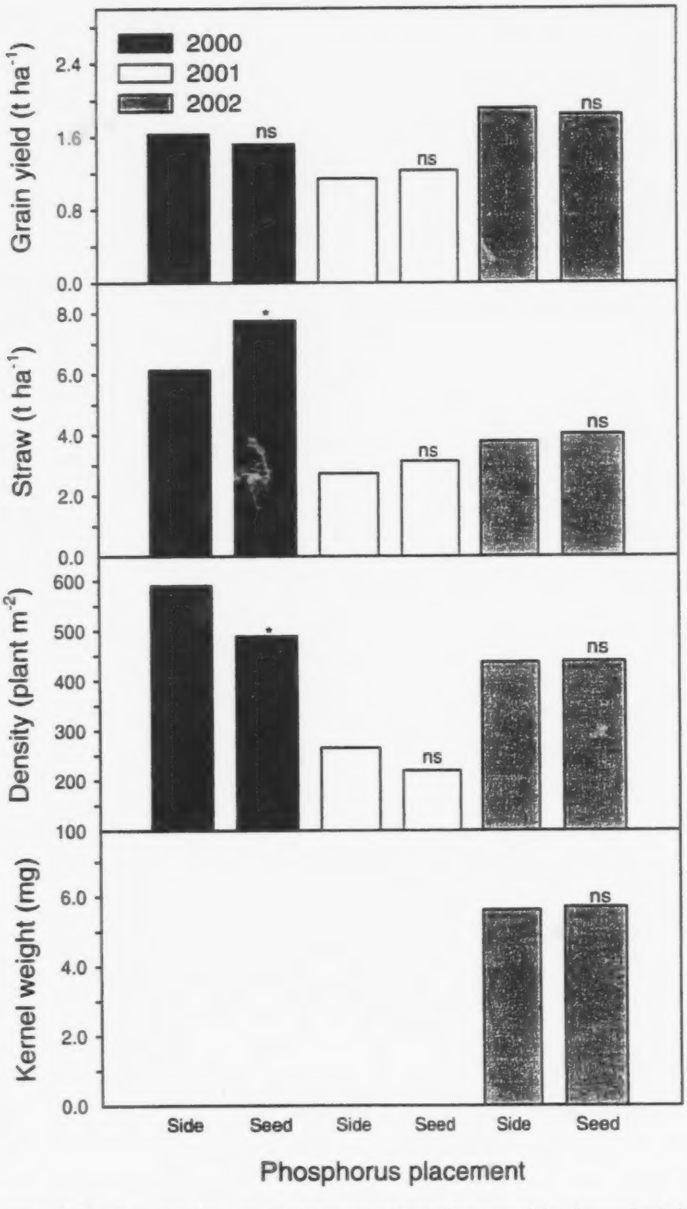

Fig. 36. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in flax at Indian Head. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

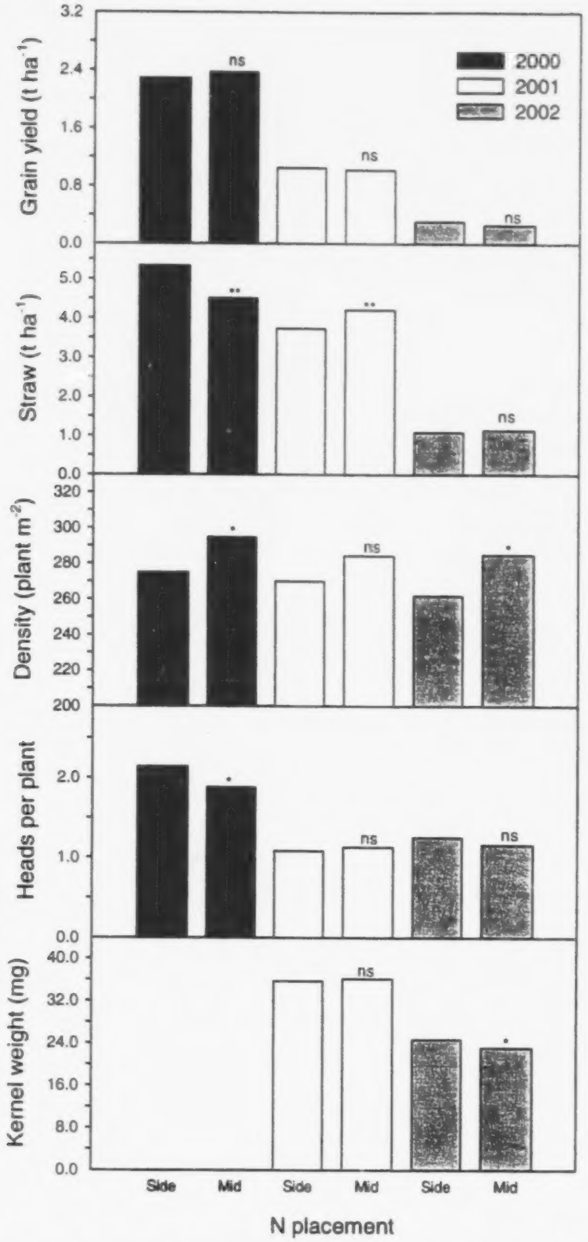

Fig. 37. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatments in wheat at Star City. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

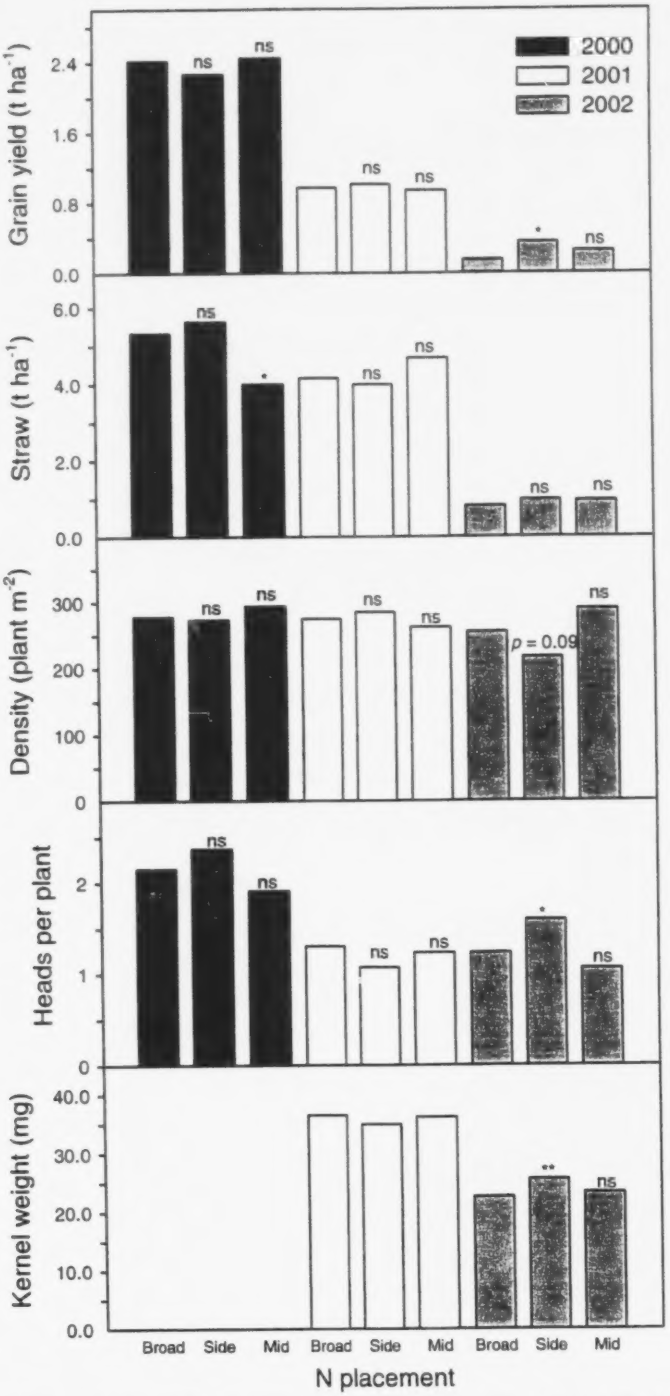

Fig. 38. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in wheat at Star City. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

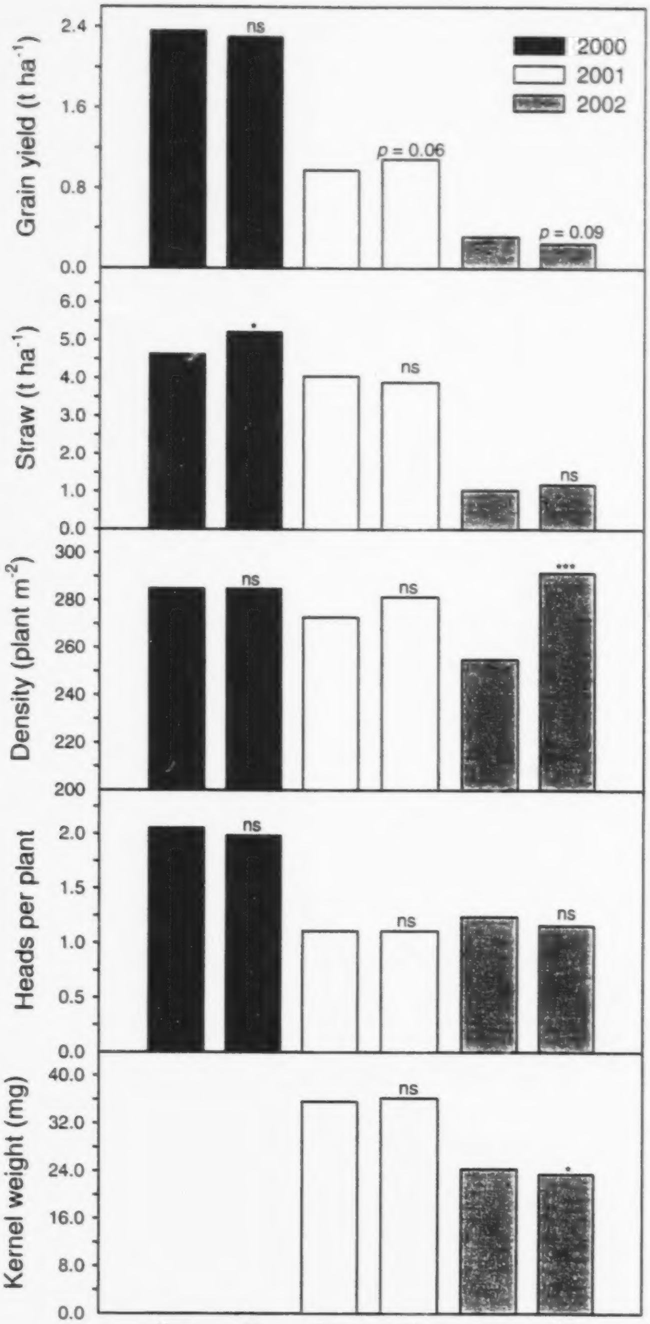

Fig. 39. Comparisons between Urea ad AA treatments in wheat at Star City. *, **, ns: significant at 0.05 and 0.01and not significant at 0.05 probability levels, respectively, within the same year.

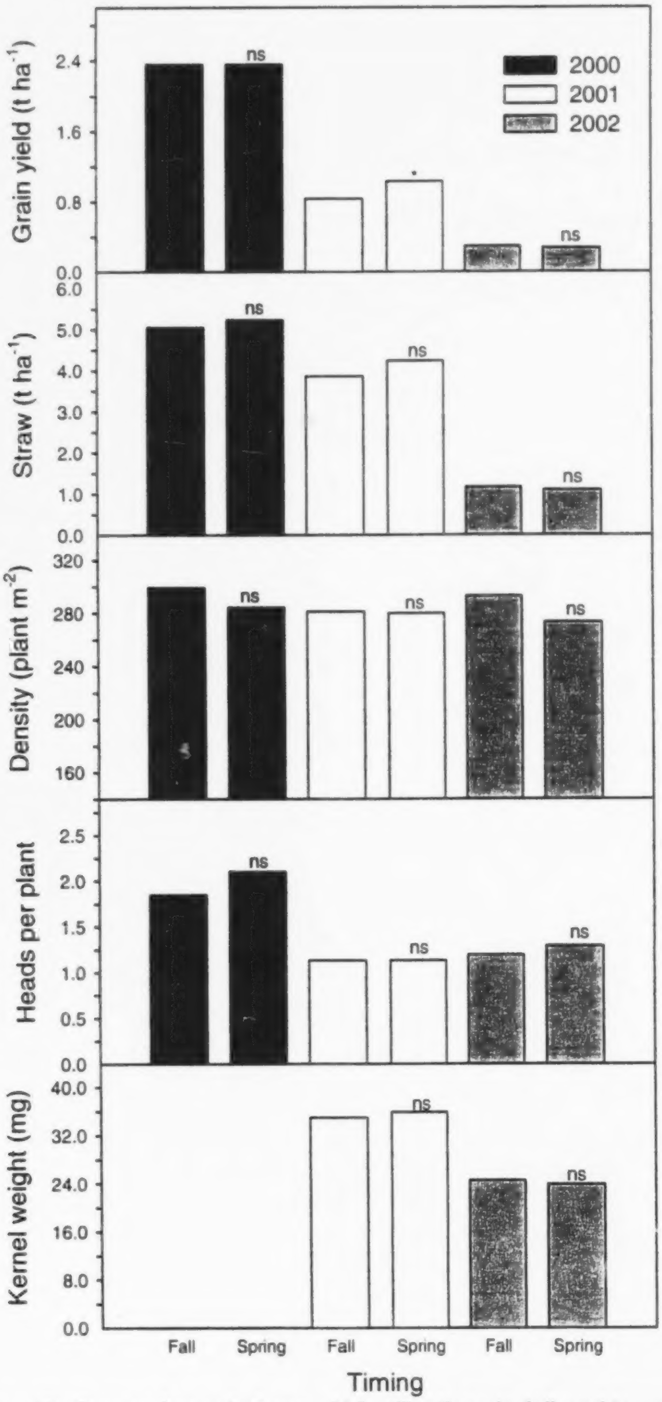

Fig. 40. Comparisons between N fertilizations in fall and in spring at medium rate in wheat at Star City. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

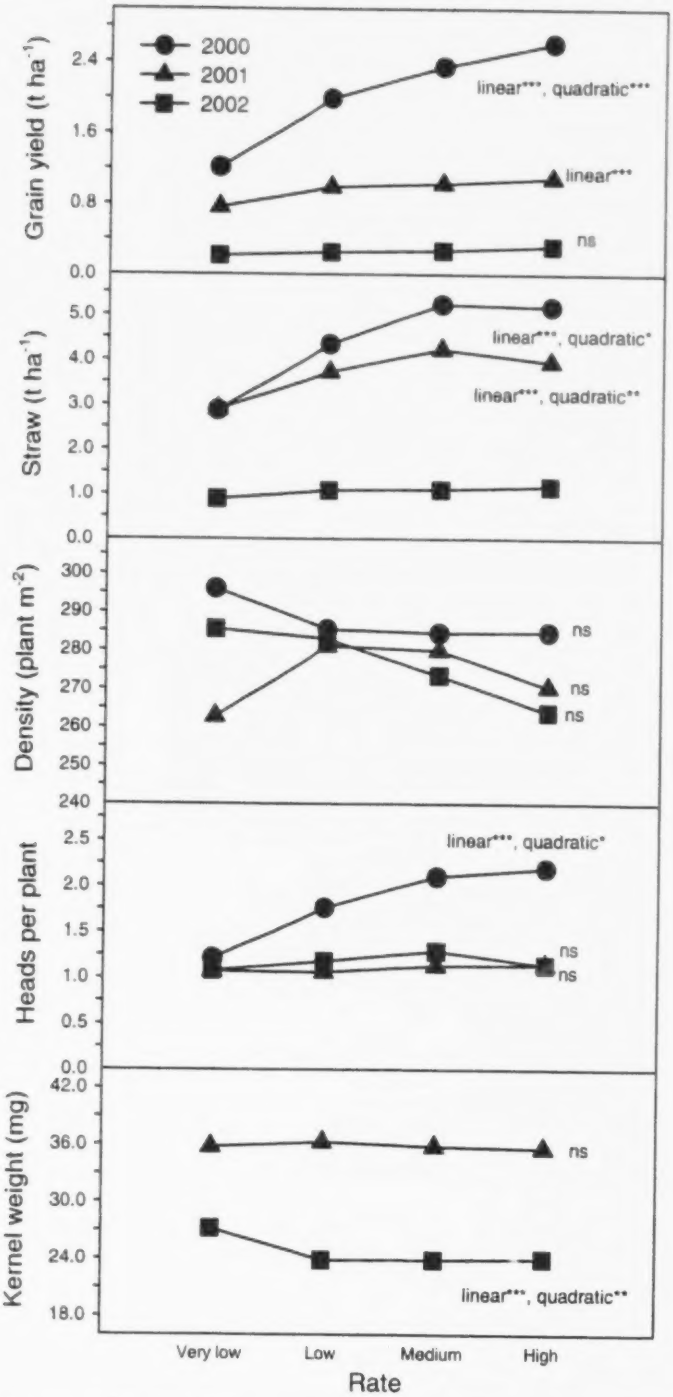

Fig. 41. Effects of N fertilizer rate on agronomic performance in wheat at Star City. *, **, ***, ns: significant at 0.05, 0.01 and 0.001 and not significant at 0.05 probability levels, respectively.

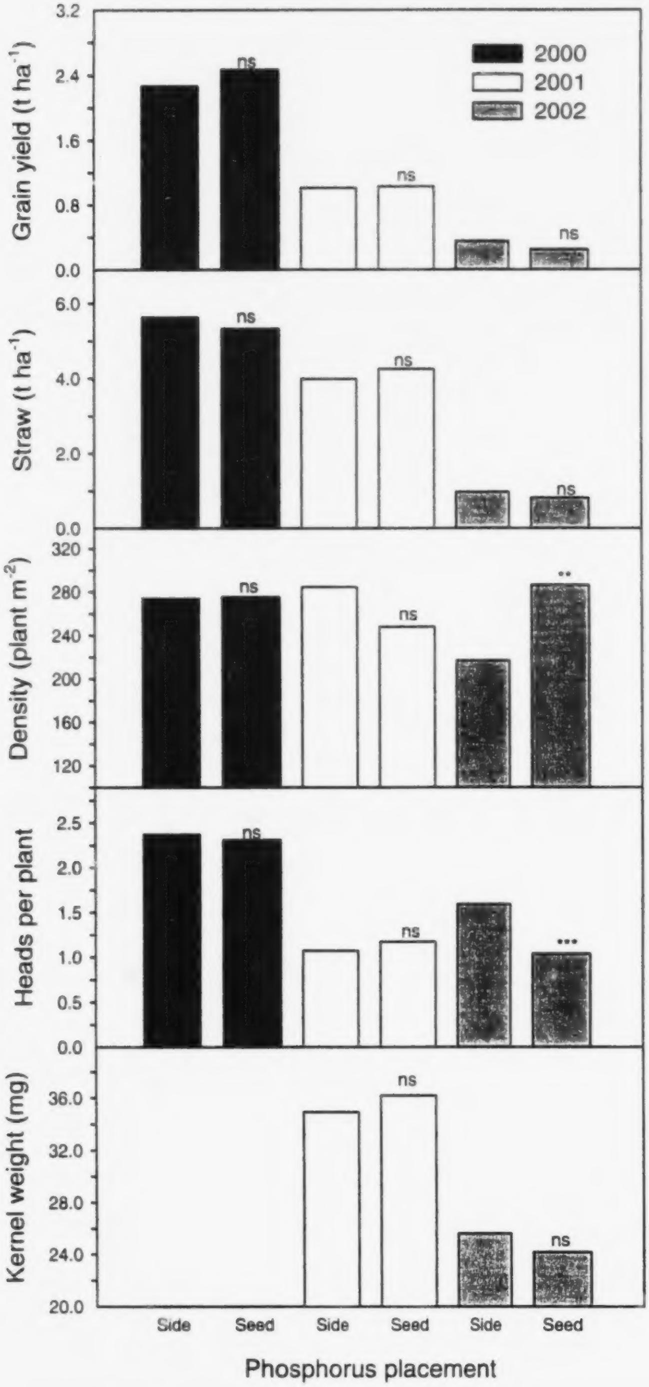

Fig. 42. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in wheat at Star City. ***, ns: significant at 0.001 and not significant at 0.05 probability levels, respectively, within the same year.

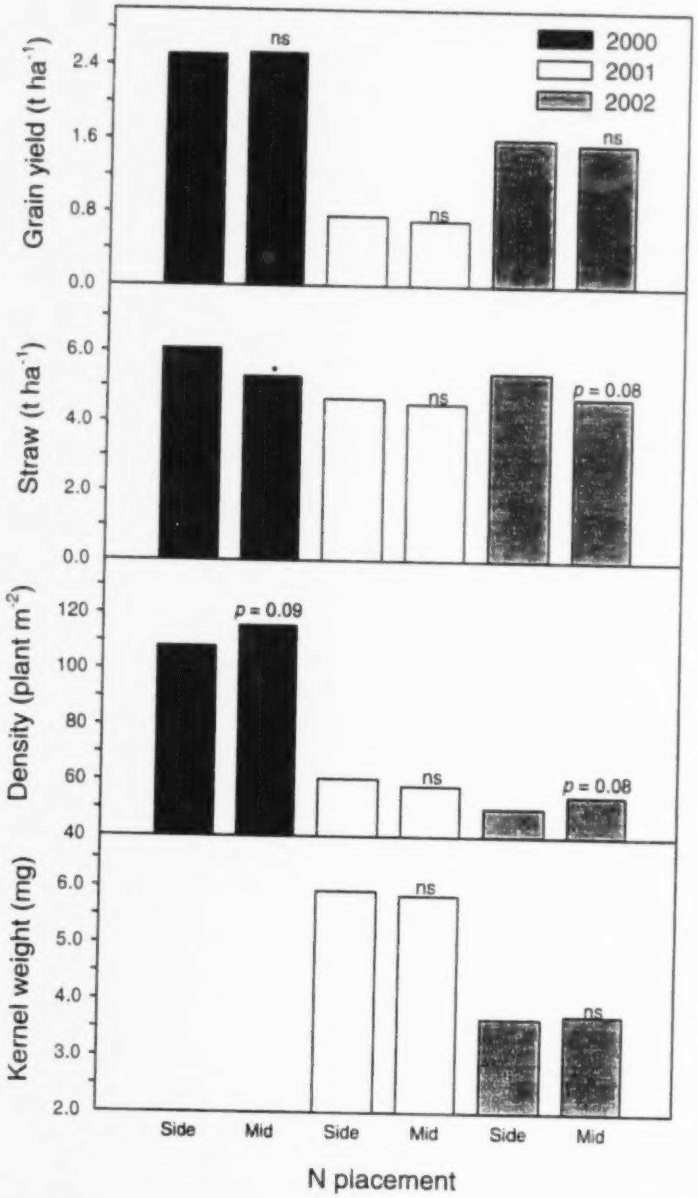

Fig. 43. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatments in canola at Star City. *, ***, ns: significant at 0.05, 0.001 and not significant at 0.05 probability levels, respectively, within the same year.

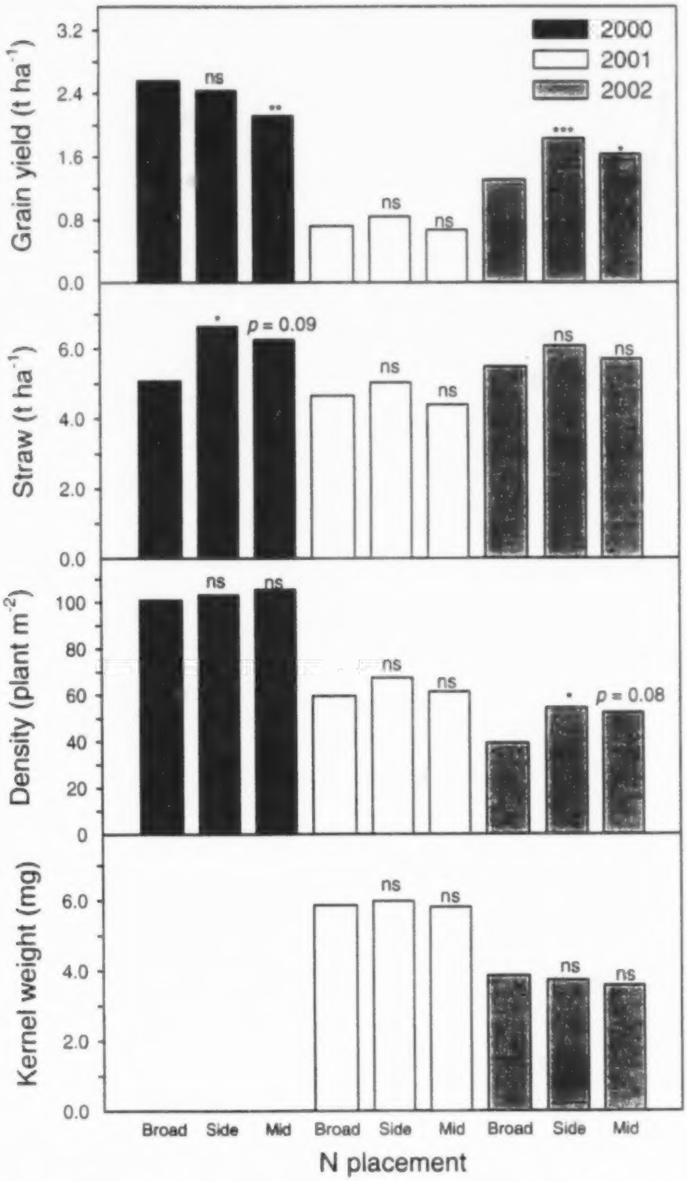

Fig. 44. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in canola at Star City. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

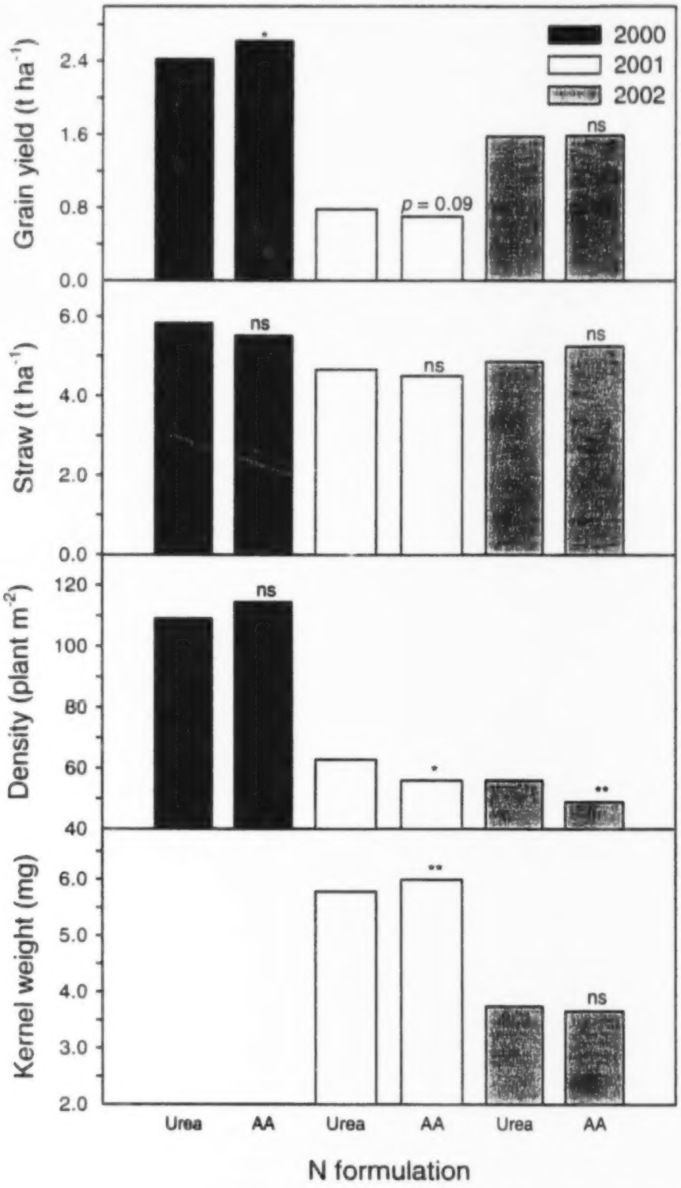

Fig. 45. Comparisons between Urea ad AA treatments in canola at Star City. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

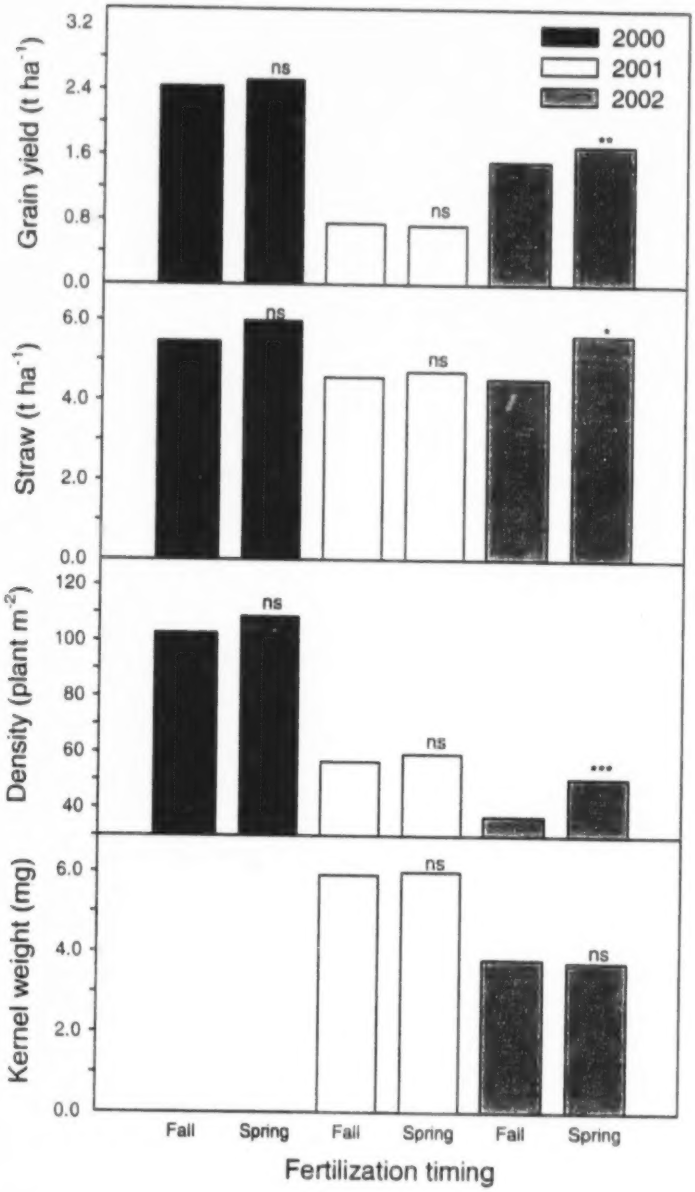

Fig. 46. Comparisons between N fertilizations in fall and in spring at medium rate in canola at Star City. ns: not significant at 0.05 probability level, within the same year.

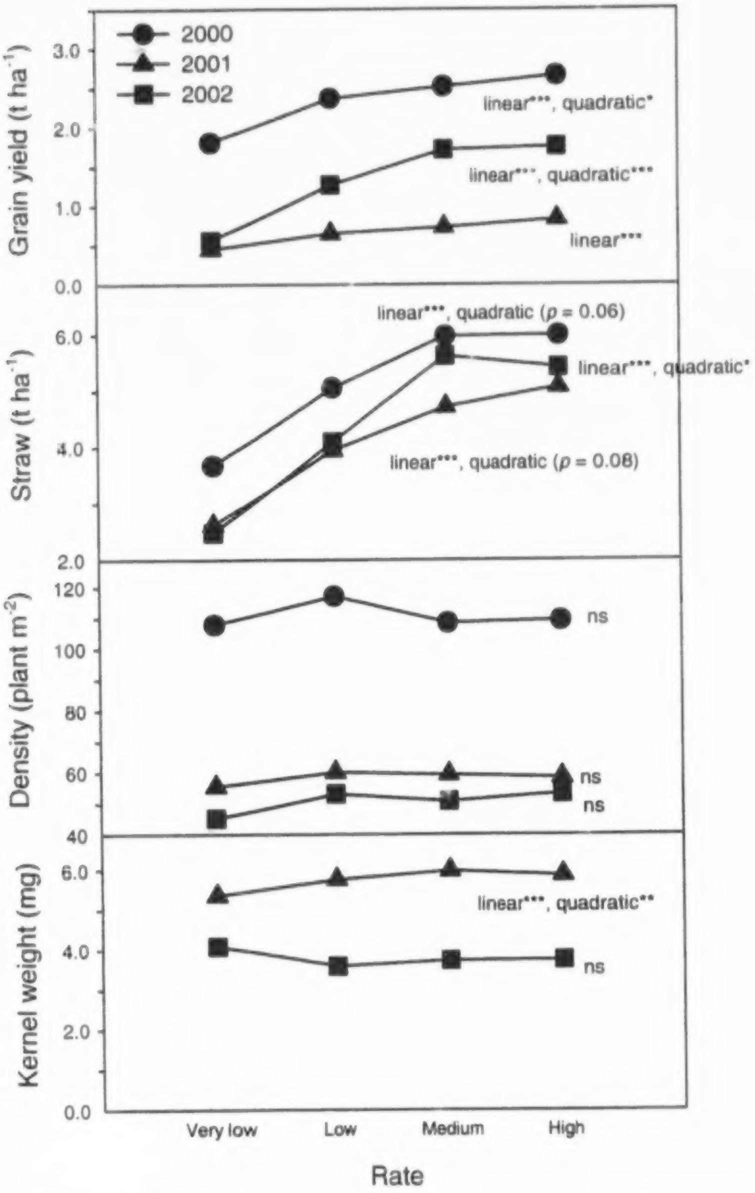

Fig. 47. Effects of N fertilizer rate on agronomic performance in canola at Star City. *, **, ***, ns: significant at 0.05, 0.01 and 0.001 and not significant at 0.05 probability levels, respectively.

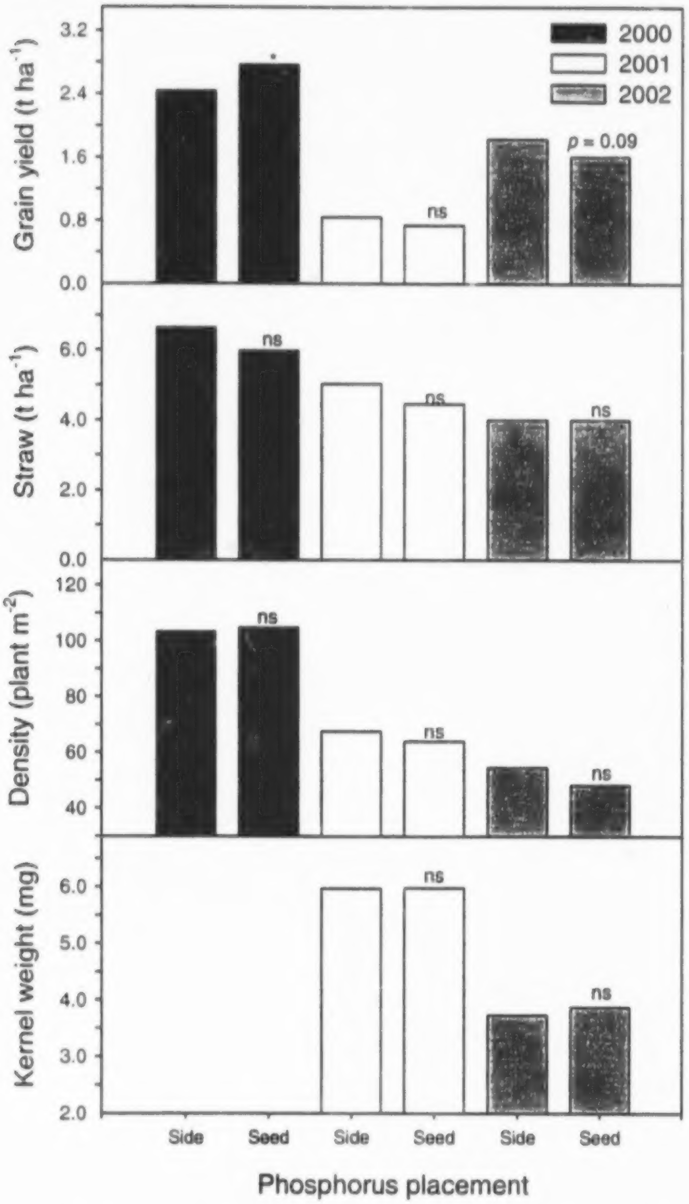

Fig. 48. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in canola at Star City. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

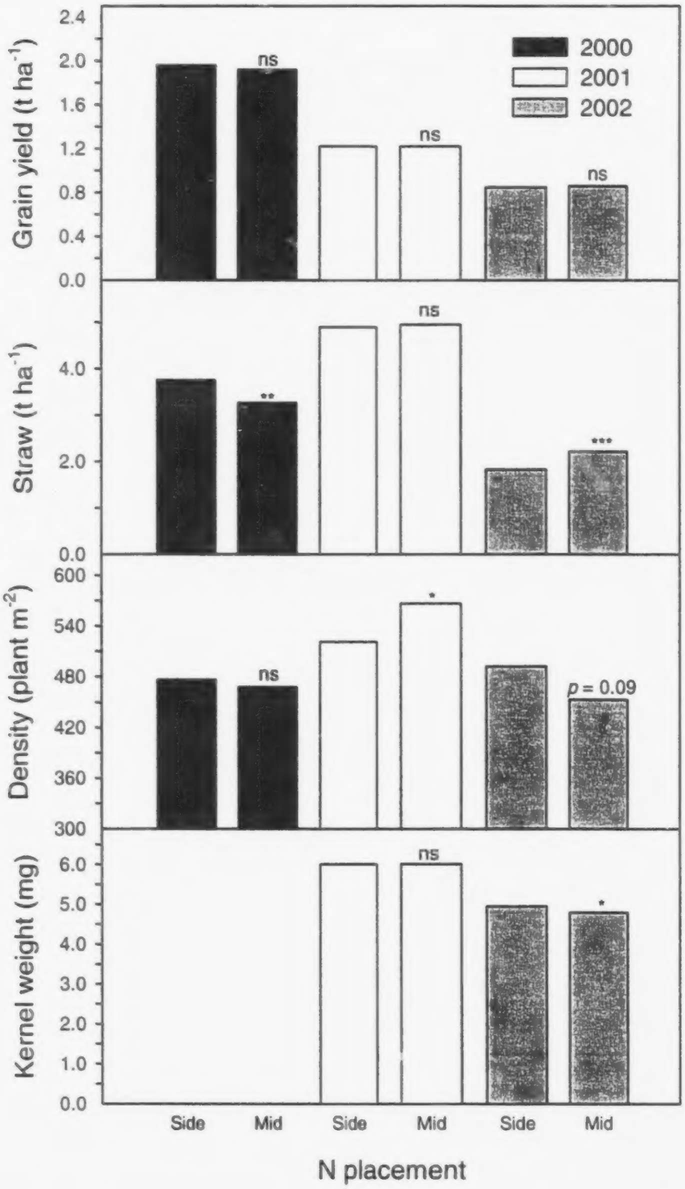

Fig. 49. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatmentsin flax at Star City. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

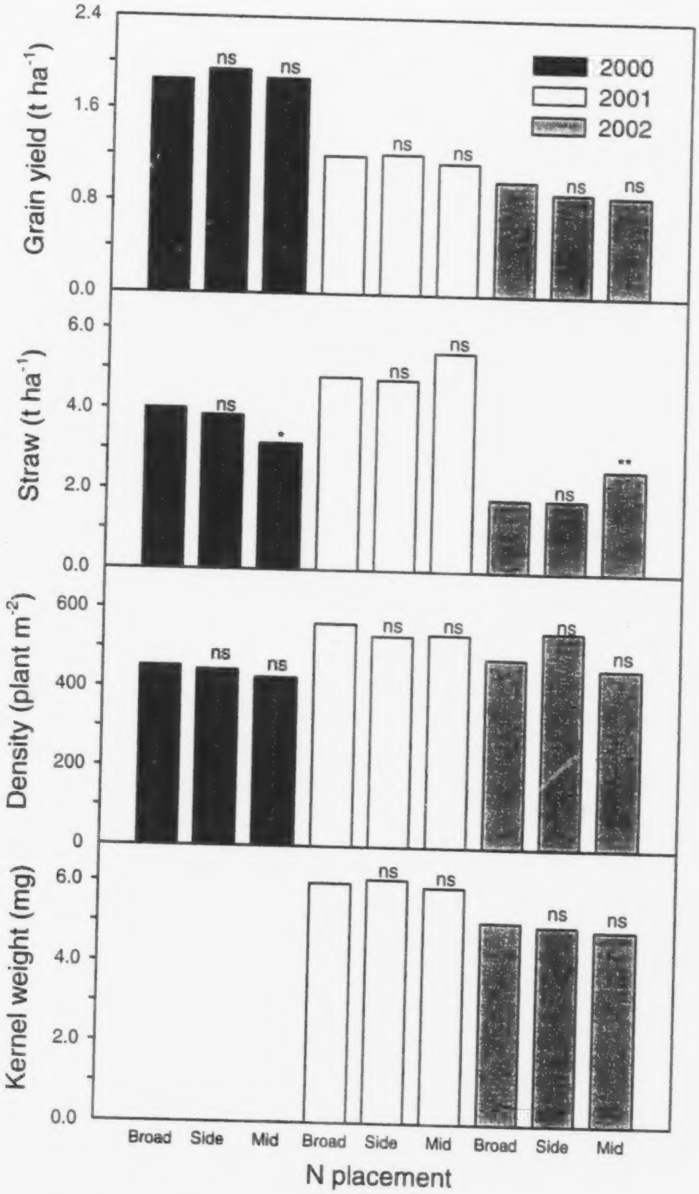

Fig. 50. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in flax at Star City. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

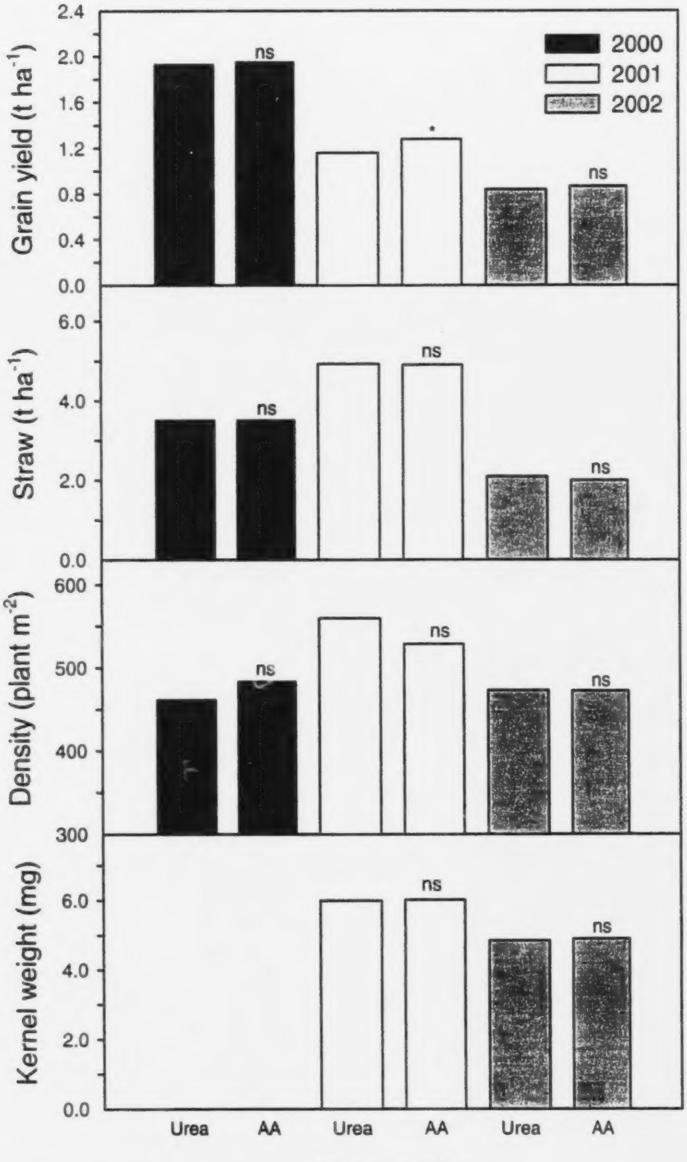

Fig. 51. Comparisons between Urea ad AA treatments in flax at Star City. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

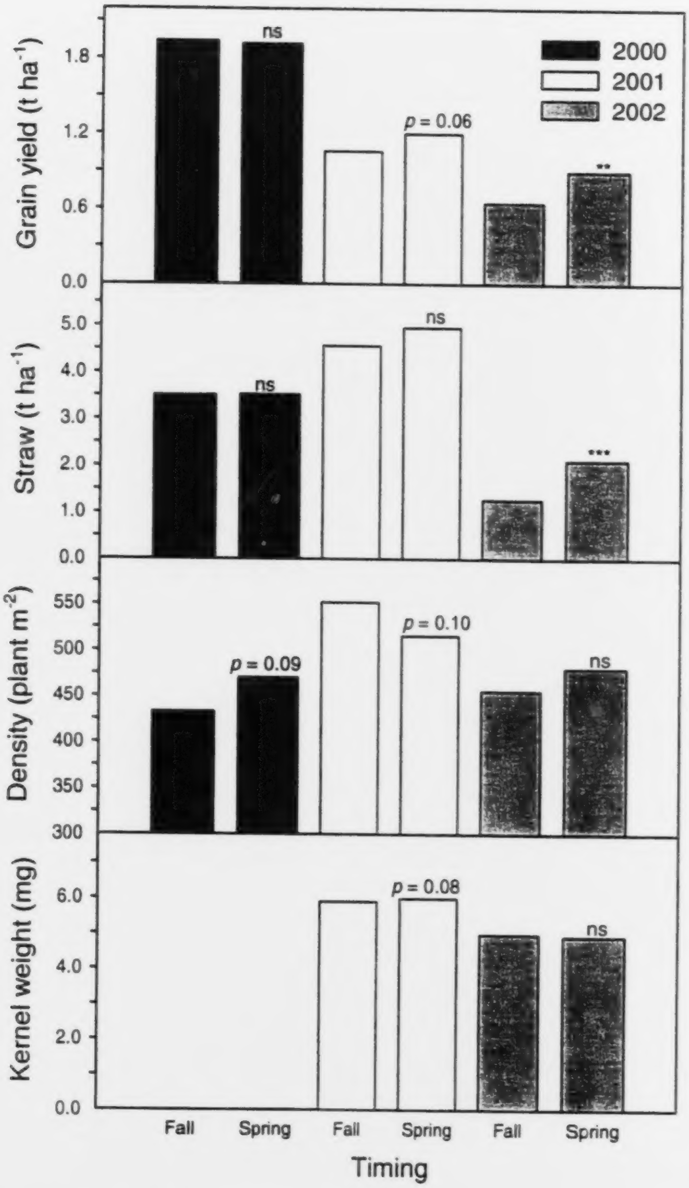

Fig. 52. Comparisons between N fertilizations in fall and in spring at medium rate in flax at Star City. *, **, ns: significant at 0.01, 0.05 and not significant at 0.05 probability level, within the same year.

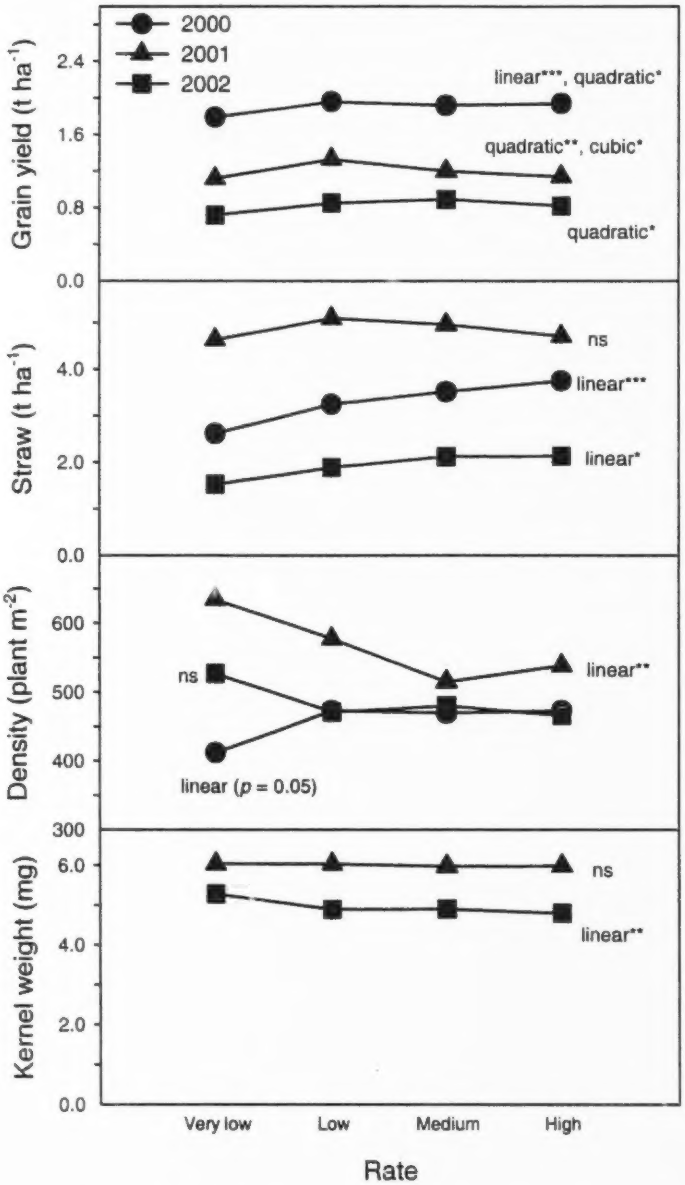

Fig. 53. Effects of N fertilizer rate on agronomic performance in flax at Star City. *, ***, ns: significant at 0.05 and 0.001 and not significant at 0.05 probability levels, respectively.

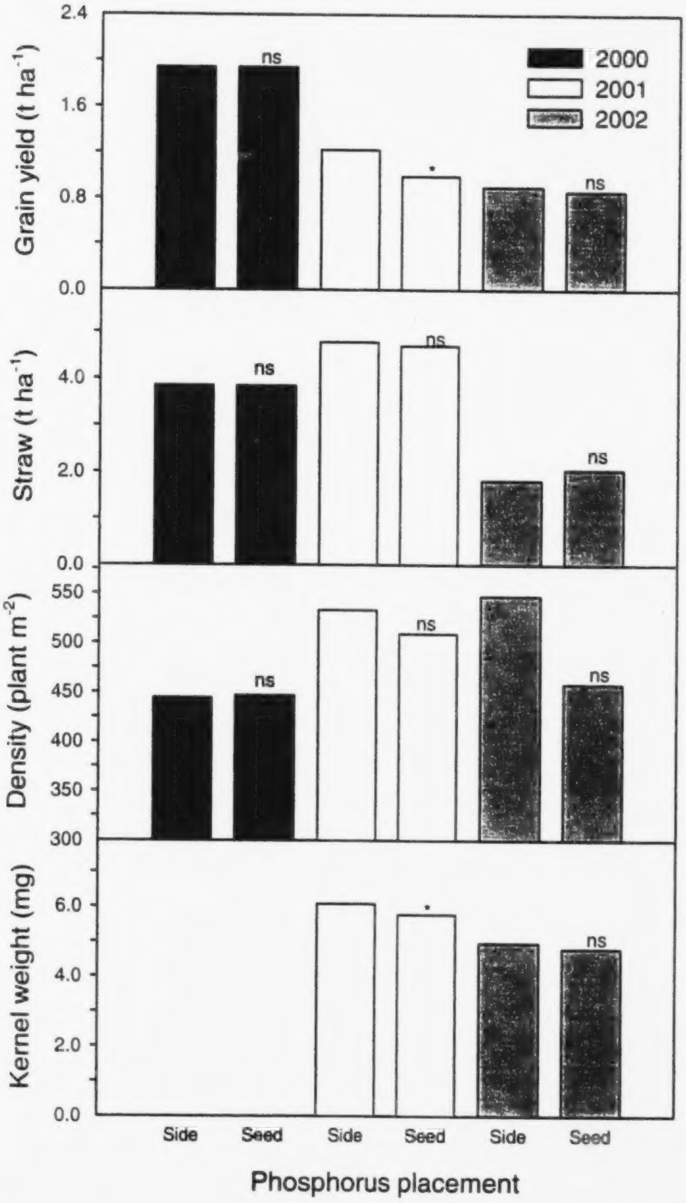

Fig. 54. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in flax at Star City. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

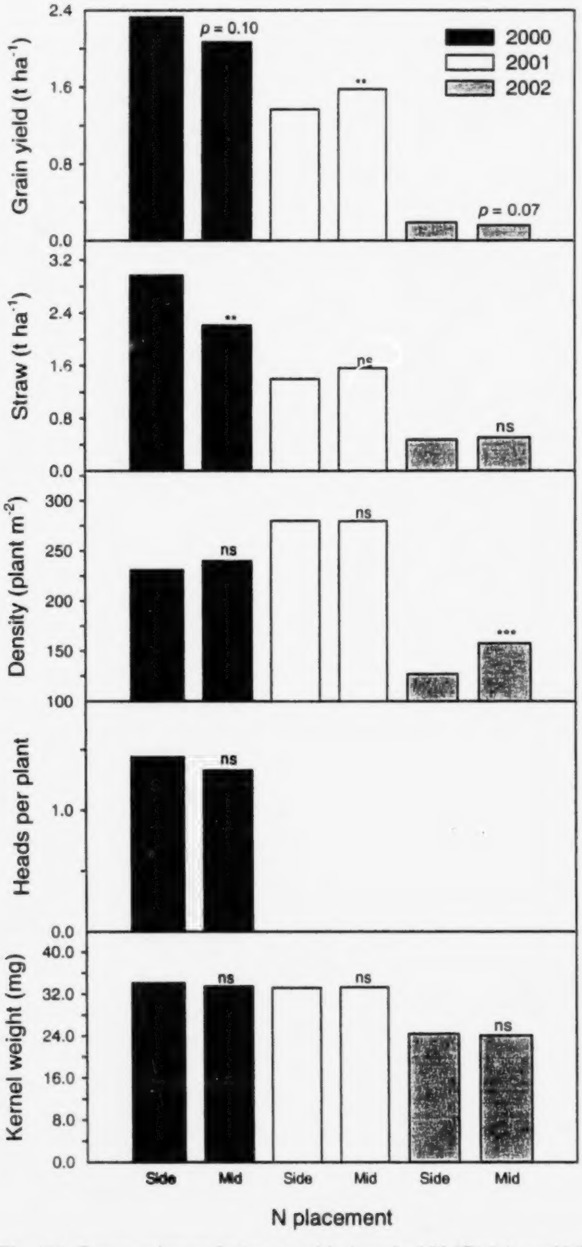

Fig. 55. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatments in wheat at Scott. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

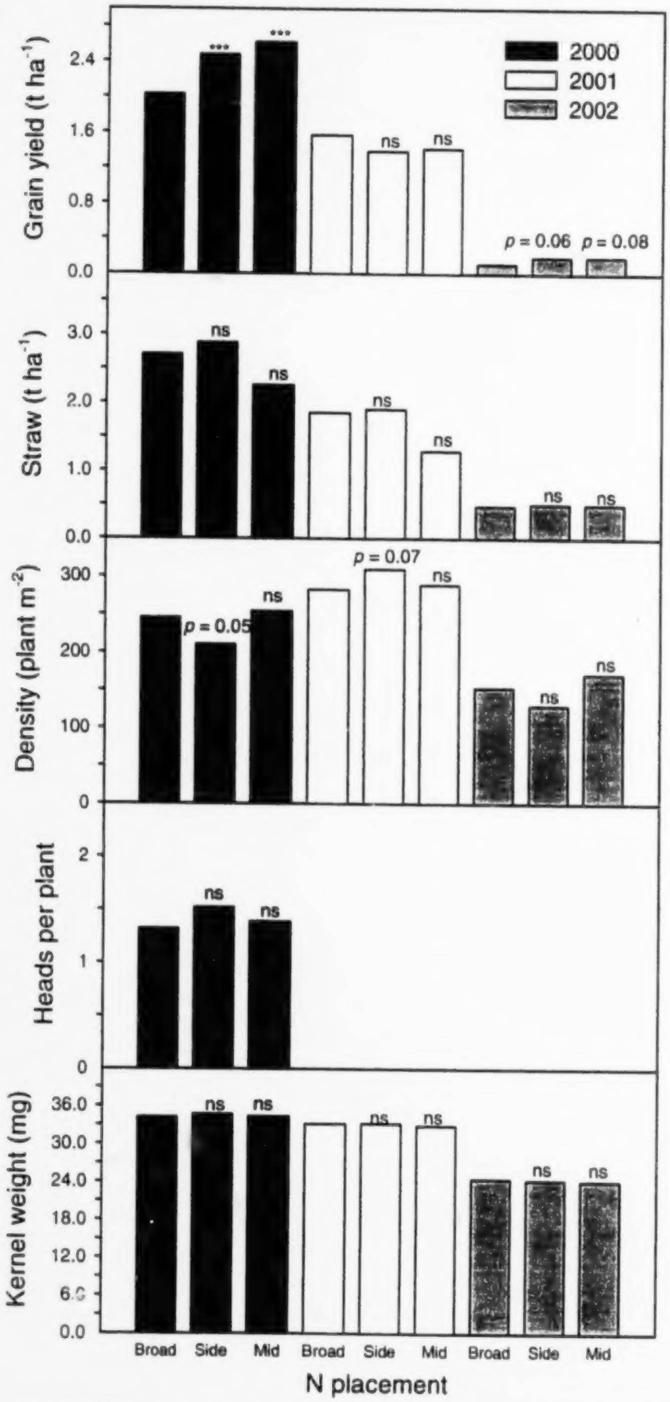

Fig. 56. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in wheat at Scot *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

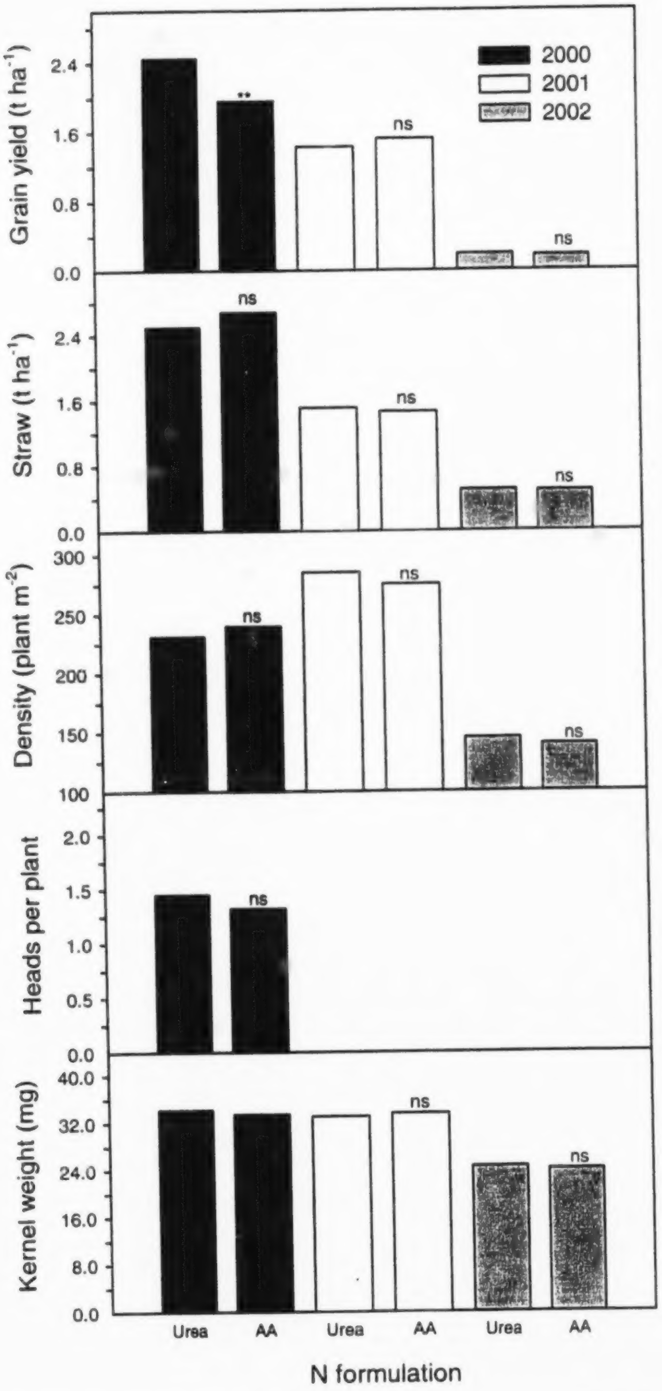

Fig. 57. Comparisons between Urea ad AA treatments in wheat at Scott. *, **, ns: significant at 0.05 and 0.01and not significant at 0.05 probability levels, respectively, within the same year.

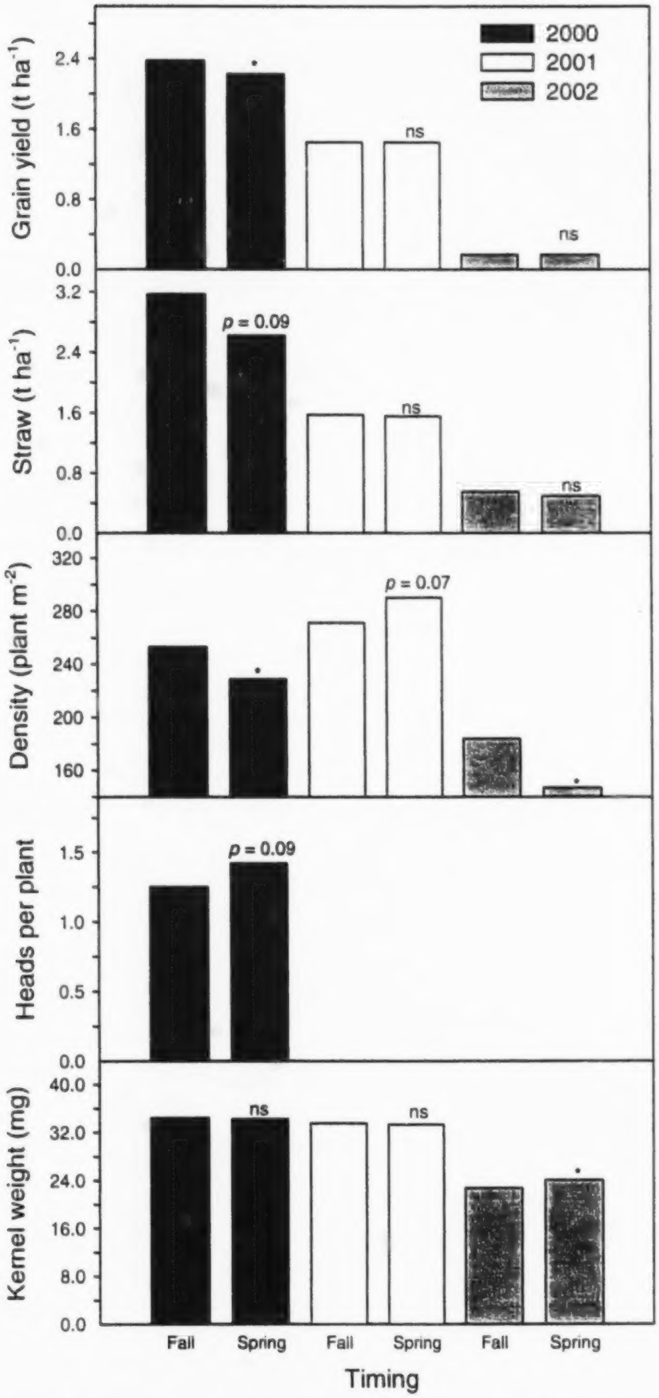

Fig. 58. Comparisons between N fertilizations in fall and in spring at medium rate in wheat at Scott. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

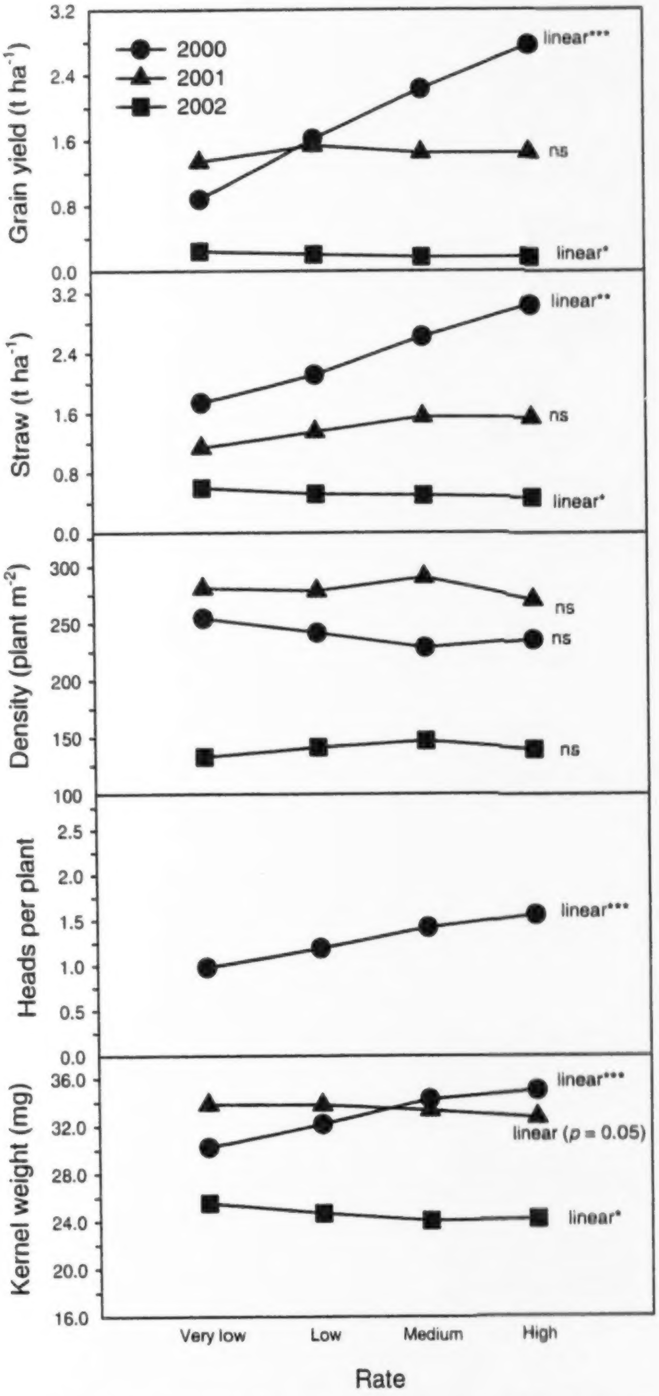

Fig. 59. Effects of N fertilizer rate on agronomic performance in wheat at Scott. *, **, ***, ns: significant at 0.05, 0.01 and 0.001 and not significant at 0.05 probability levels, respectively.

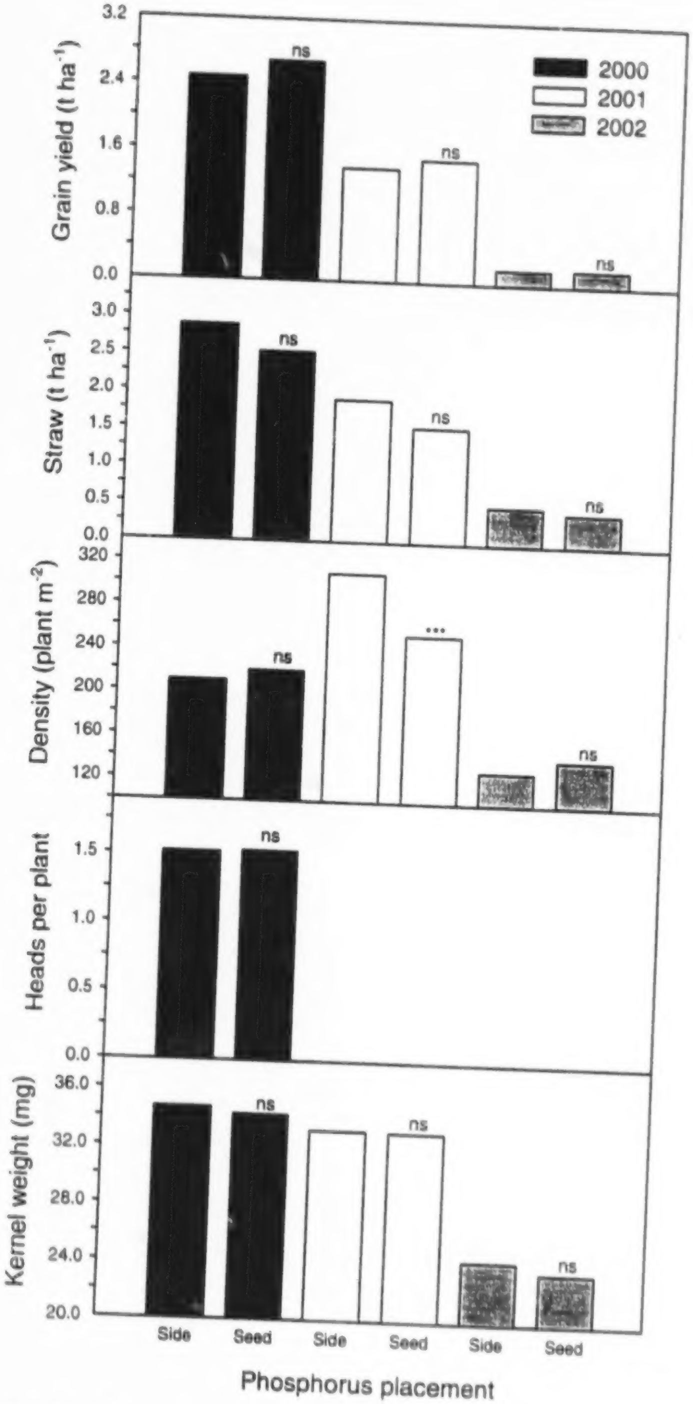

Fig. 60. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in wheat at Scott. ***, ns: significant at 0.001 and not significant at 0.05 probability levels, respectively, within the same year.

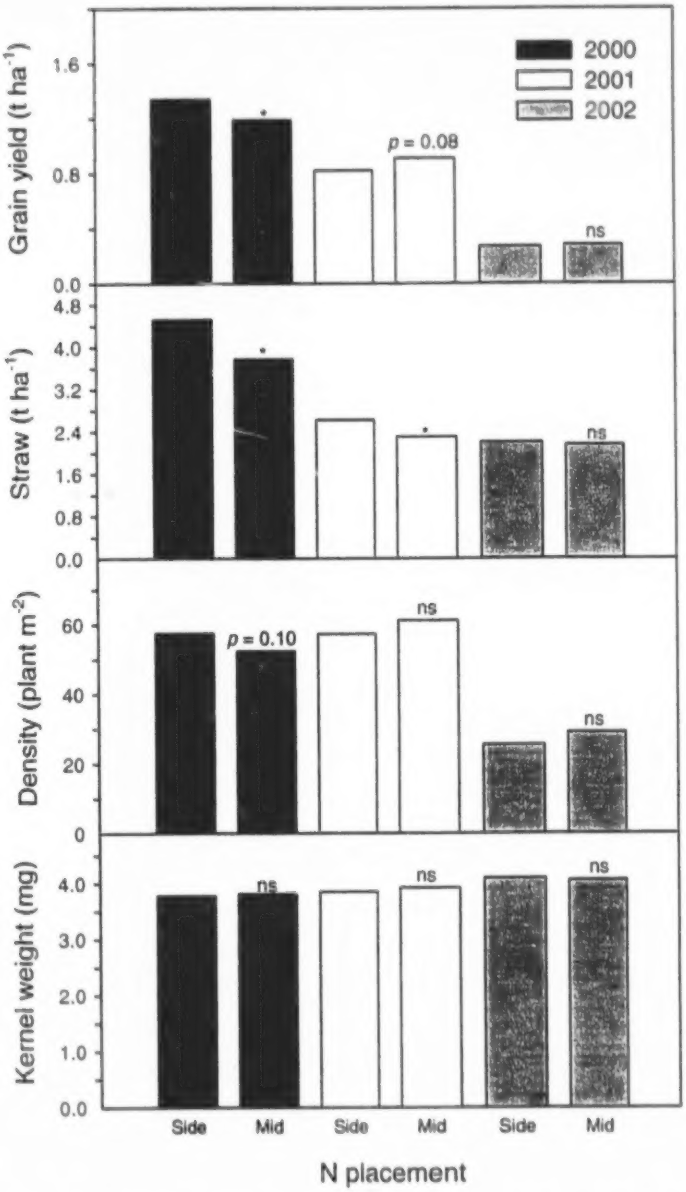

Fig. 61. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatments in canola at Scott. *, ***, ns: significant at 0.05, 0.001 and not significant at 0.05 probability levels, respectively, within the same year.

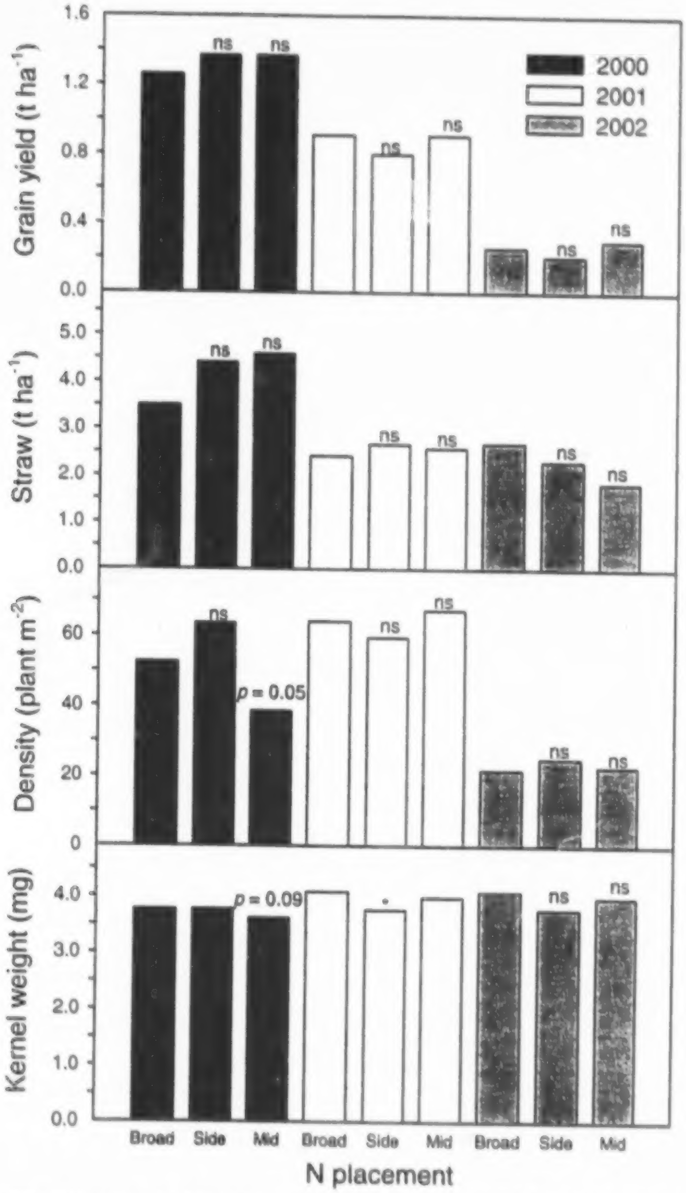

Fig. 62. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in canola at Scott. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

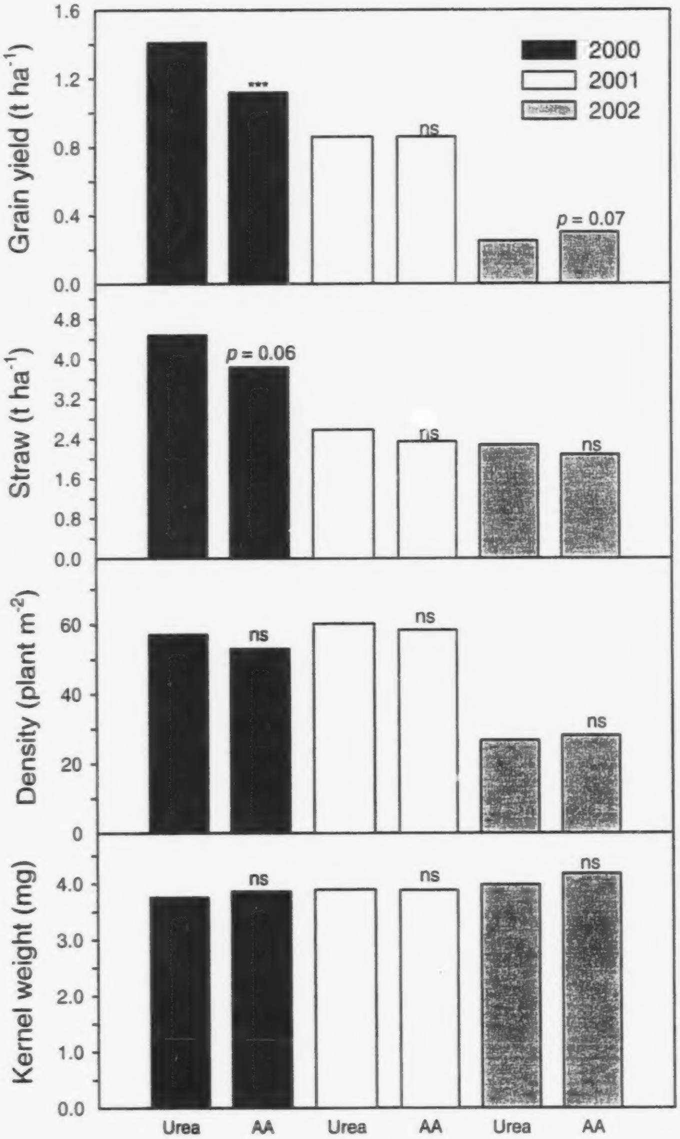

Fig. 63. Comparisons between Urea ad AA treatments in canola at Scott. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

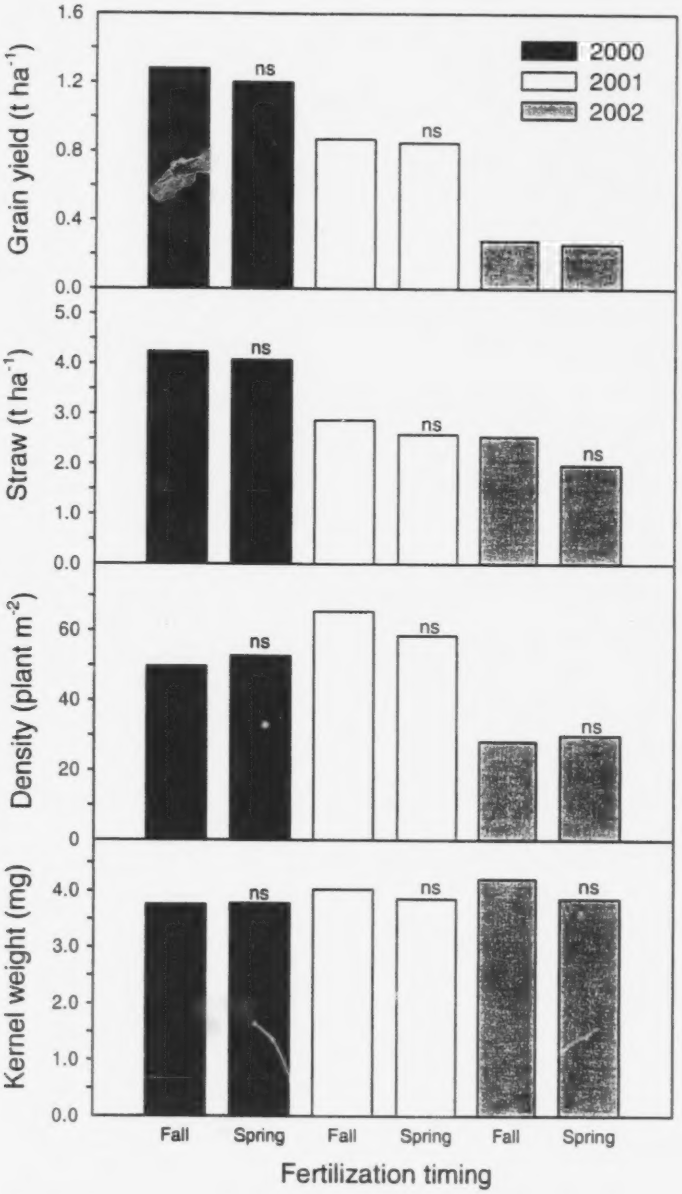

Fig. 64. Comparisons between N fertilizations in fall and in spring at medium rate in canola at Scott. ns: not significant at 0.05 probability level, within the same year.

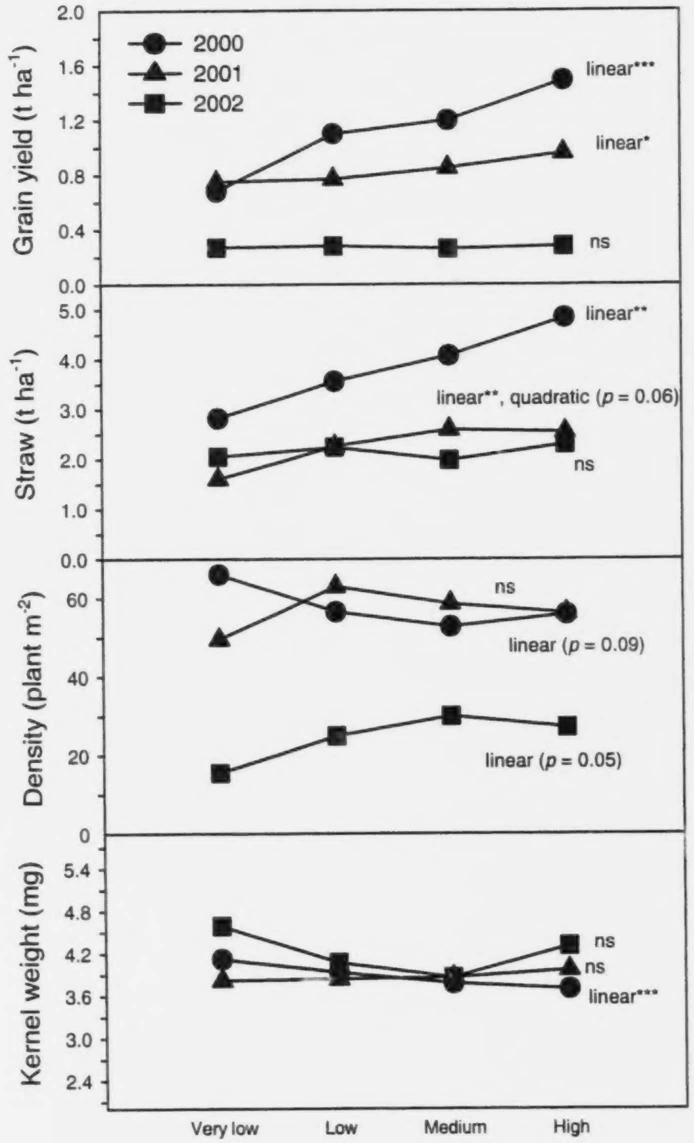

Fig. 65. Effects of N fertilizer rate on agronomic performance in canola at Scott. *, **, ***, ns: significant at 0.05, 0.01 and 0.001 and not significant at 0.05 probability levels, respectively.

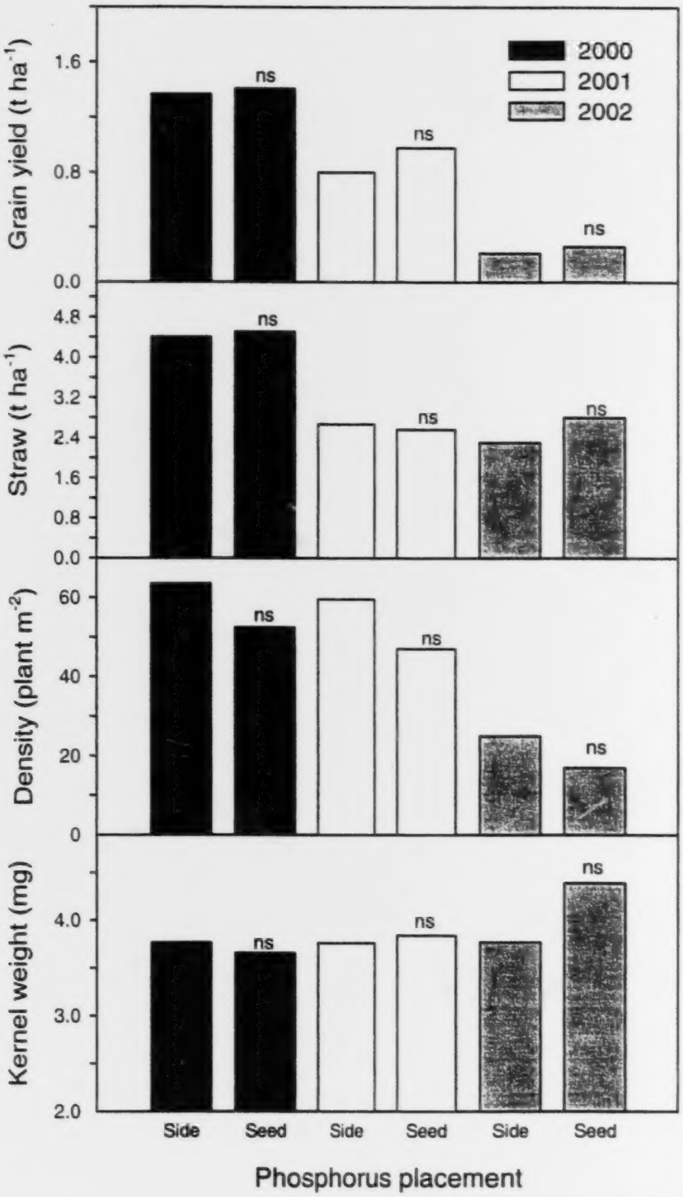

Fig. 66. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in canola at Scott. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

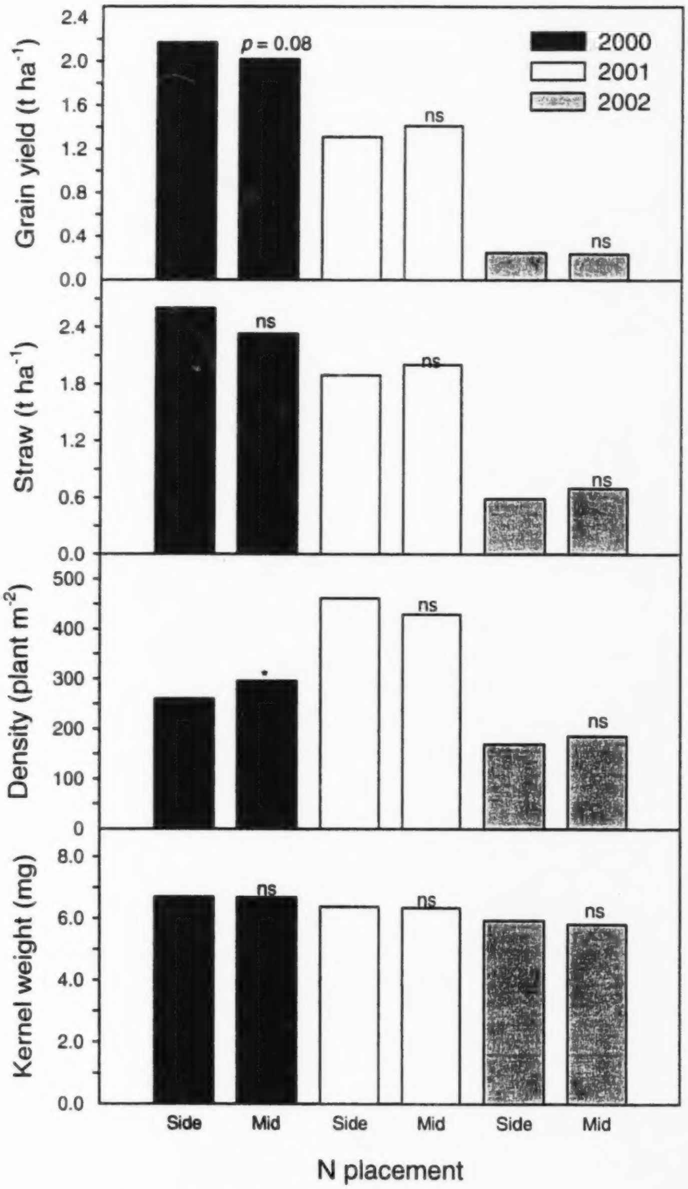

Fig. 67. Comparisons between side banded N (Side) and Mid-row banded N (Mid) treatmentsin flax at Scott. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

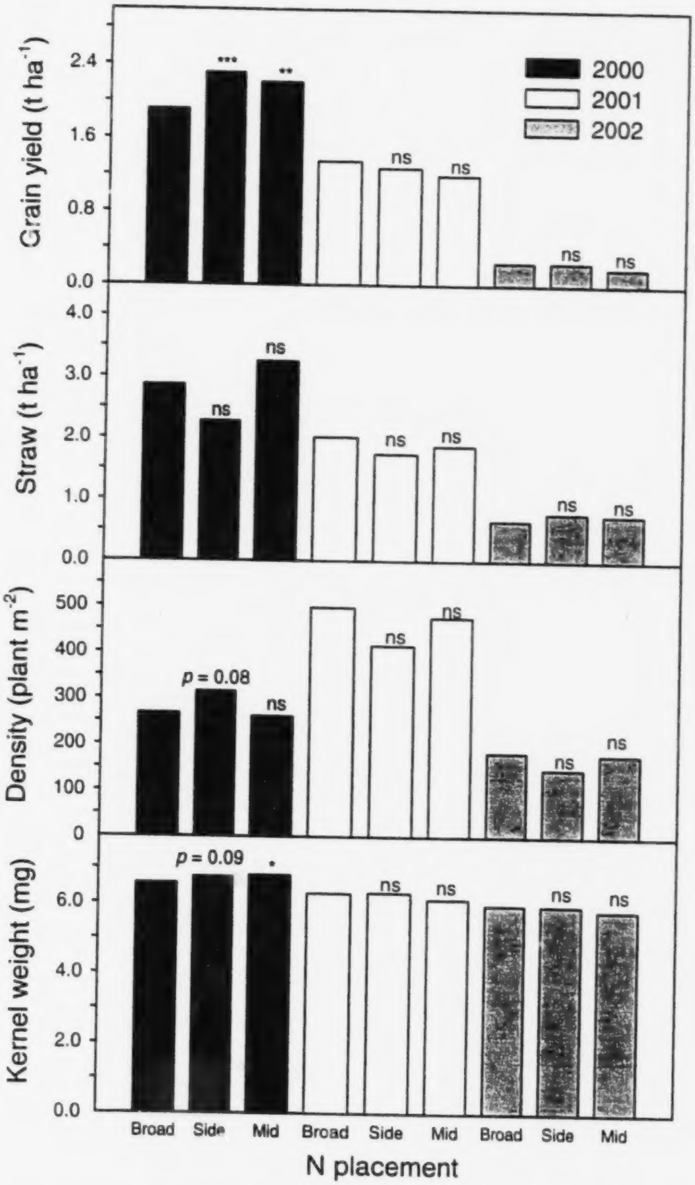

Fig. 68. Effects of N broadcast (Broad), side band (Side) and mid-row band (Mid) in the treatments of urea at medium rate in flax at Scott *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year, compared with broadcast placement.

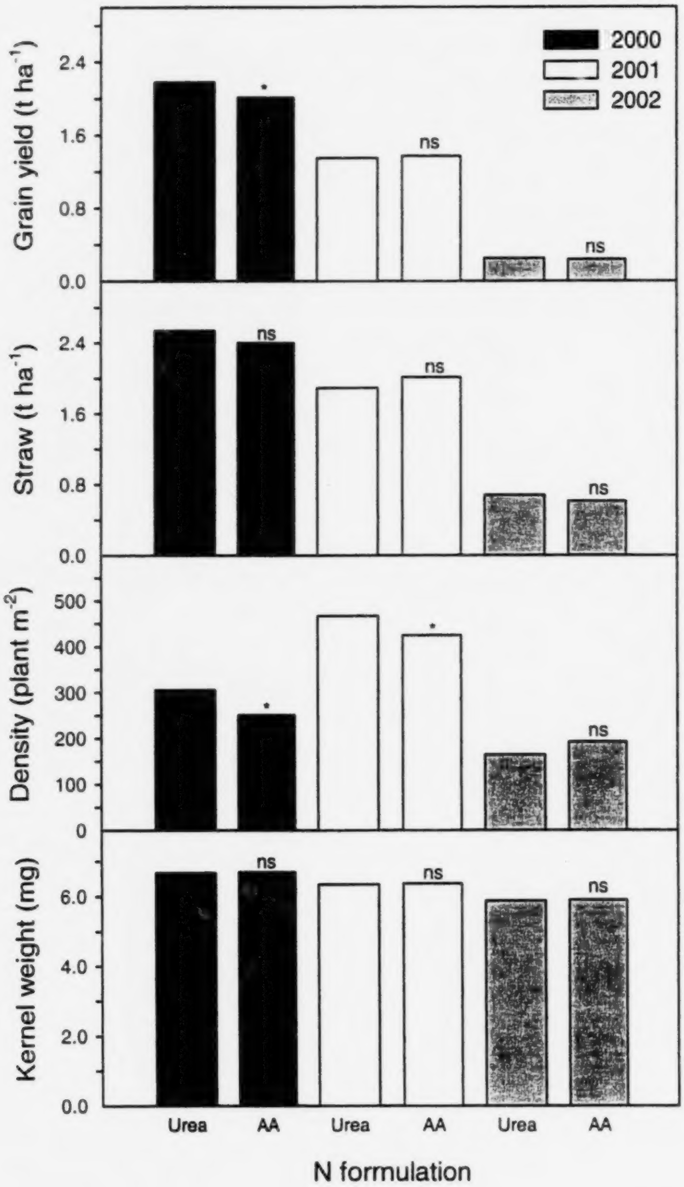

Fig. 69. Comparisons between Urea ad AA treatments in flax at Scott. *, ns: significant at 0.05 and not significant at 0.05 probability levels, respectively, within the same year.

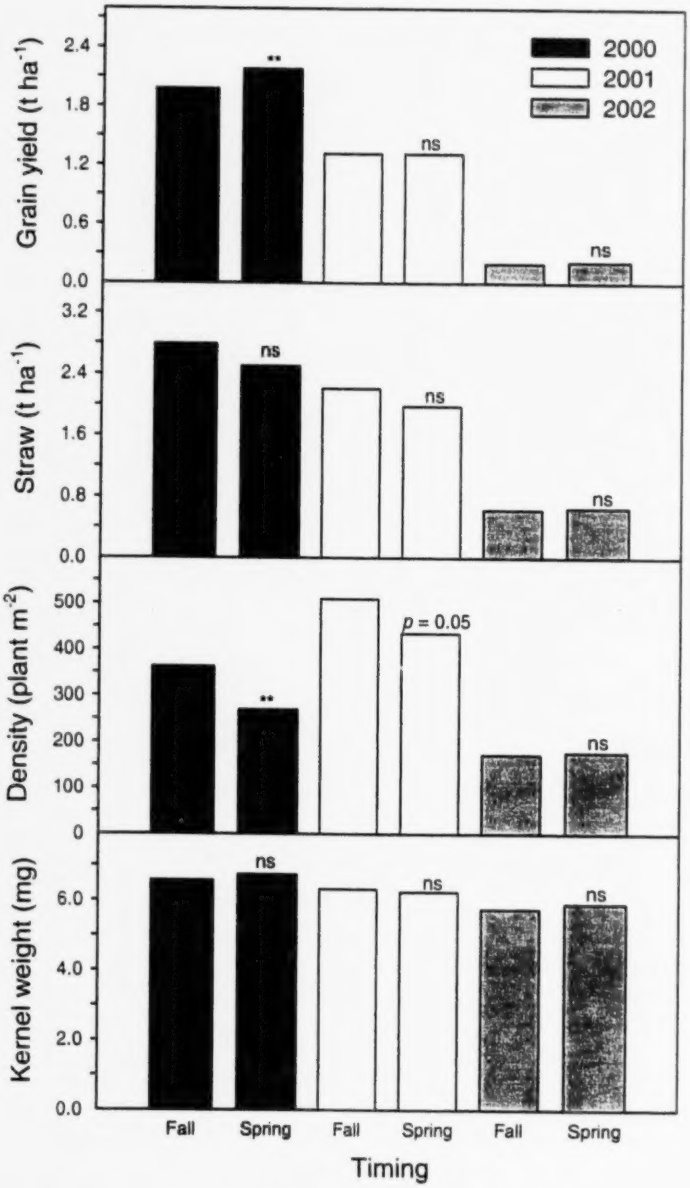

Fig. 70. Comparisons between N fertilizations in fall and in spring at medium rate in flax at Scott. *, **, ns: significant at 0.01, 0.05 and not significant at 0.05 probability level, within the same year.

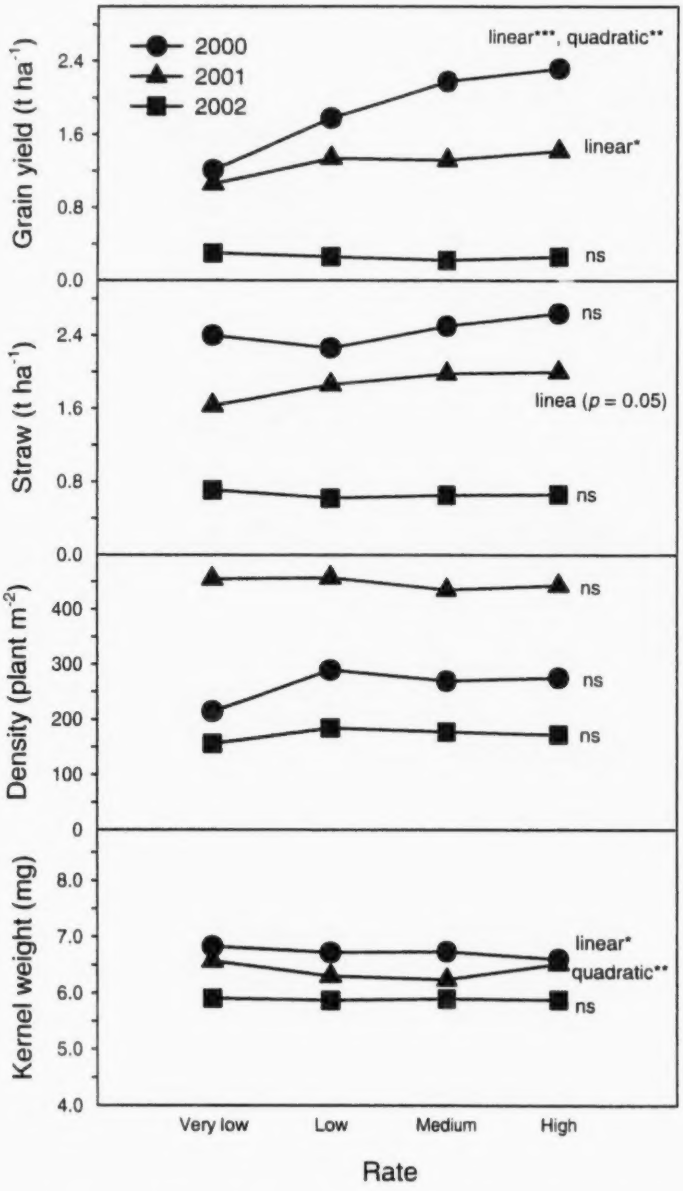

Fig. 71. Effects of N fertilizer rate on agronomic performance in flax at Scott. *, ***, ns: significant at 0.05 and 0.001 and not significant at 0.05 probability levels, respectively.

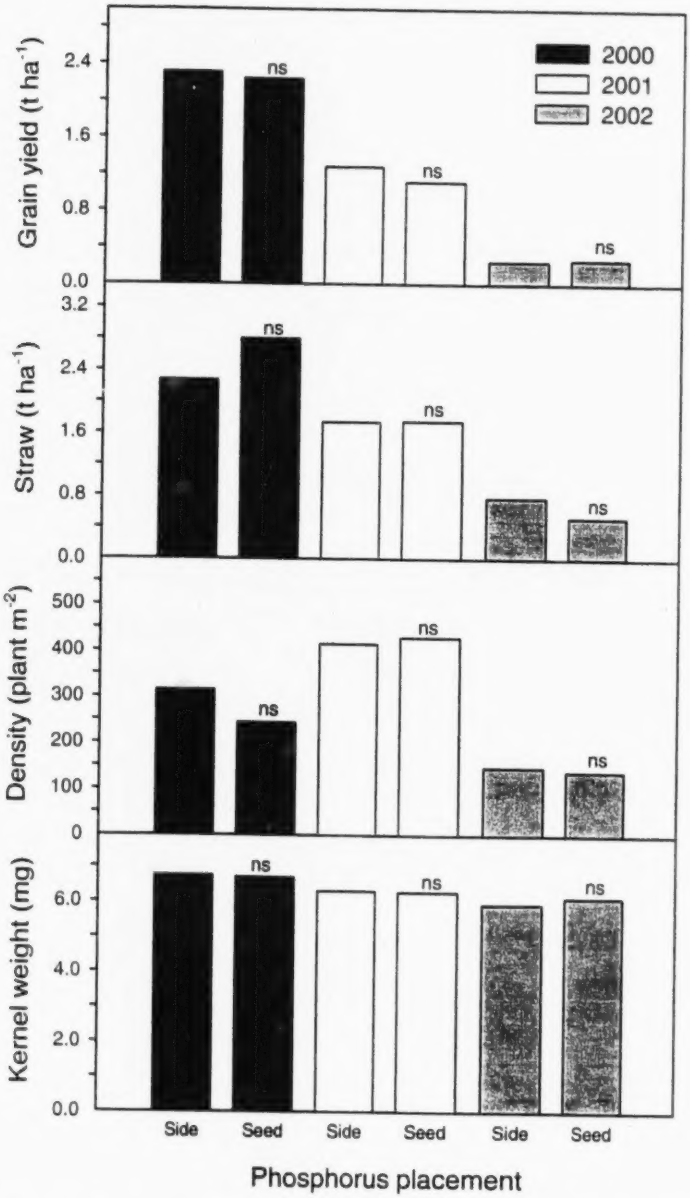

Fig. 72. Comparisons between phosphorus side-banded (Side) and phosphorus placed with the seed (Seed) in flax at Scott. *, ns: significant and not significant at 0.05 probability levels, respectively, within the same year.

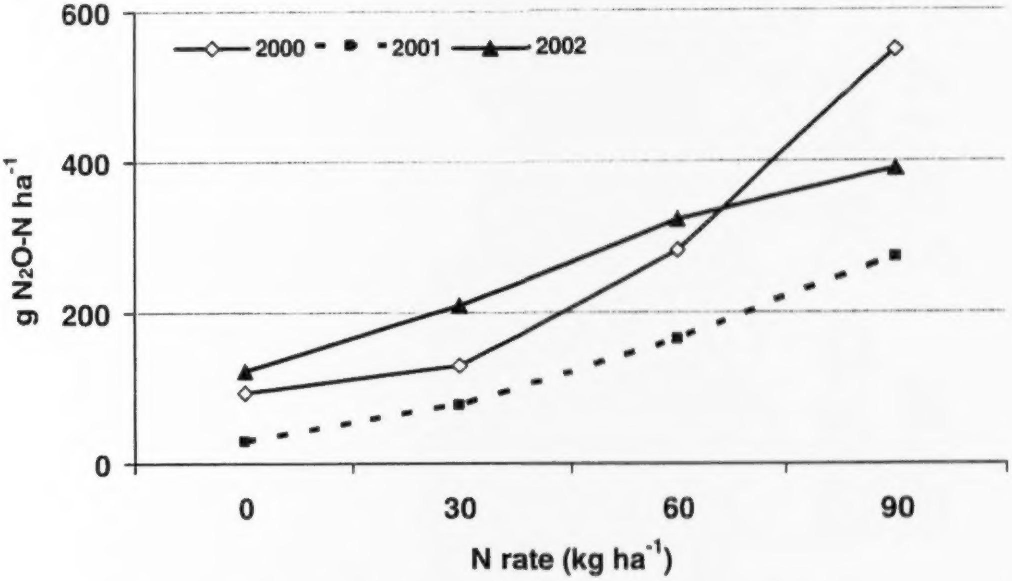

Figure 73. Influence of fertilizer N application rate on estimated cumulative N_2O emissions during the 2000, 2001 and 2002 frost-free periods at Swift Current.

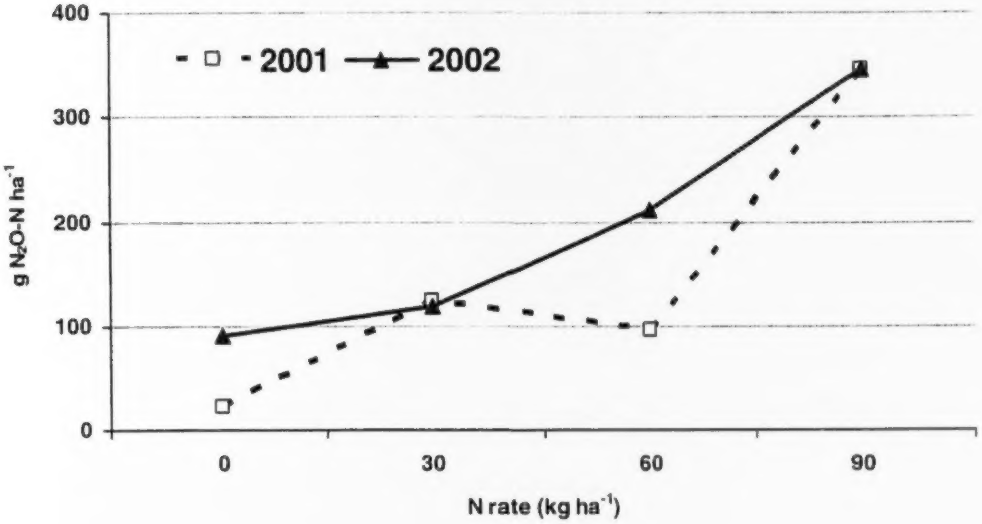

Figure 74. Influence of fertilizer N application rate on estimated cumulative N_2O emissions during the 2001 and 2002 frost-free periods at Scott.

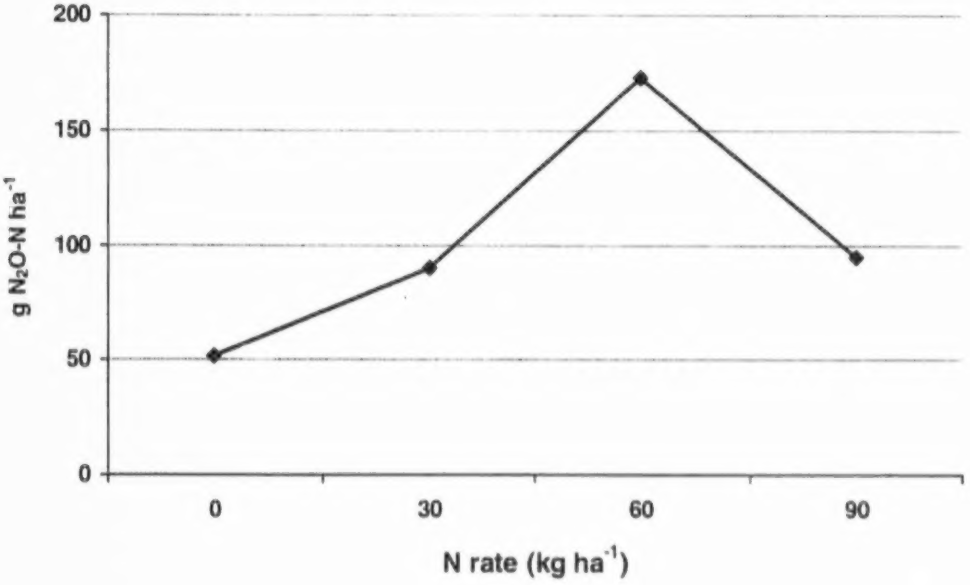

Figure 75. Influence of N rate on cumulative annual N_2O emissions at Indian Head during the 2000-2001 annual cycle.